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Rainfall Characterization of the Catchment Area of Ensenada, Baja California, Mexico

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Abstract

Precipitation constitutes an important part of the hydrologic cycle, since it produces the planet's renewable water resources. In semi-arid regions, like Ensenada, Baja California, Mexico, where the rainfall throughout the year is generally scarce, it is of great importance to be able to predict the precipitation and make necessary arrangements to prepare for draughts or floods.

The main objective of this thesis is the rainfall characterization of the catchment area of Ensenada, Baja California, Mexico.

In order to do that, 60 years of data from seventeen meteorological stations was studied, previous restoration by means of multiple regression method and NIPALS algorithm. The restoration was followed by obtaining extreme and mean climate for each station. In order to establish a trend existence, that is, if the rainfall has experimented a decrease or an increase through the years, the Mann-Kendall trend test was applied. Following that, cross-correlation technique was applied so as to establish a correlation existing between the mean and maximum precipitation values and the North Pacific climate index and the El Niño index.

The results of this thesis include the Weibull distribution parameters for extreme and mean climates for the seventeen meteorological stations, tabulated and graphical Mann-Kendall trend test results for mean and maximum precipitation values for the seventeen stations and graphical results for the correlation between the climate indexes and mean and maximum precipitation values.

These results provide an insight into the rainfall characterization of the area may be used as a management tool for decision makers and good water use policy.

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Introduction

As the world's population grows, the need for water grows with it. And even if the recent studies suggest that the world's population has been experiencing a decline (Ortiz-Ospina and Roser, 2016) the disproportionate exploitation of our water resources has already taken its toll. Already we are using our fresh water at a rate far in excess of the recharge rates throughout the world.

The general global response to water shortage is to dig deeper and deeper wells. Though this solution has provided relief for much of the population, digging deeper wells has resulted in alarming drops in the level of water available in aquifers. These drops in the water level allow contamination from salt water entering the aquifers or even the surface ground collapsing into the aquifer causing its irreversible loss.

Unfortunately, even in light of this unsustainable consumption, diarrheic disease due to contaminated drinking water remains a primary cause of childhood mortality. The environmental and public health challenges faced by Mexico embody many of these global struggles. According to 2005's Mexico's Secretariat of Health report, 17% of the Mexican population does not have access to drinking water of "appropriate bacteriological quality." The Mexican government considers the lack of clean water a national security issue.

Two thirds of the territory of Mexico is considered arid or semi-arid, with annual precipitation of less than 500mm, whereas the southeast is humid with average precipitations of over 2000mm per year. In the majority of the territory, the rainfall is more intense in the summer, when it is mainly torrential.

Every year Mexico receives around 1489 billion cubic meters of water in the form of precipitation. Of this water, it is estimated that 73.2% evaporates and returns to the atmosphere, 22.1% runs off into rivers and streams and the remaining 4.7% naturally filters through to the subsoil and recharges the aquifers.

Mexico being an extensive country (1.964 million km²) with its 37 hydrological regions and 4080 stations in operation to measure the climate and hydrometric variables would be an enormous feat to take, this study has been centred in Ensenada, Baja California.

The Baja California Peninsula is one of the most arid areas in Mexico and water shortages are becoming critical. As an example, the Maneadero aquifer, one of four aquifers supplying water to the City of Ensenada, has a calculated overexploitation of 16000 ac-ft/year (20Mm³/year) and has caused severe deterioration of groundwater due to saline intrusion (Daesslé et al, 2005). Ensenada is growing at a rate of 3.7% (INEGI, 1997) and so is the demand on water supply. Other aquifers in Baja California Peninsula suffer from saltwater intrusion (9 out of 87), overdraft (8 out of 87) and soil salinization and brackish groundwater (5 out of 87).

Baja California state disposes of 4626hm³/year of renewable water sources, that is, the maximum quantity of water that can feasibly be used every year (renewed by rainfall and the imports) that compares poorly to all other Hydrological Administrative Regions, being the 2nd lowest of the thirteen (Baja California Peninsula, Northwest, Northern Pacific, Balsas, Central Basins of the North, Rio Bravo, Cuencas Centrales del Norte, Lerma-Santiago-Pacific, Northern

Gulf, Central Gulf, Southern Border, Yucatan Peninsula and Waters of the Valley of Mexico). It is also the 2nd lowest in total mean natural surface runoff (3367 hm³/year) and total mean aquifer recharge (1259 hm³/year).

Baja California state has another particularity in relation to all the other states: the precipitation there mainly takes place in winter whereas in all the other states the precipitation occurs predominantly between June and September. Moreover, the Baja California Peninsula suffers from drought: in 2008 the drought registered was from abnormally dry to severe drought categories (CONAGUA, 2010).

In the Public Registry of Water Duties (REPDA), the volumes allocated to the users of the nation's water are registered. In this Registry, the uses of water are classified into 12 groups, which for practical purposes have been grouped into five headings; four that correspond to offstream uses, namely agriculture, public supply, self-supplying industry and thermoelectric, as well as hydropower, which is considered separately since it corresponds to an instream use of water.

The 63% of the water used in Mexico for offstream uses comes from surface water sources (rivers, streams and lakes). From 2001 to 2008 this water usage has increased by 14% (44.3 to 50.22 billion m³). The greatest volume allocated for offstream uses of water is the one corresponding to agricultural activities. In Baja California Peninsula 2892.7 millions of cubic meters out of 3510.3 millions of cubic meters total (82%) were allocated for agricultural use. And more specifically, Baja California state allocated 2566.3 millions of cubic meters out of 3109.1 millions of cubic meters (82.5%) for this purpose.

The percentage of water used for offstream uses as compared to the renewable water resources is an indicator of the water stress in any given country, catchment or region. It is considered that if the percentage is greater than 40%, there is a high water stress. Baja California Peninsula experiences a water stress of 75.9%

All those numbers tell one thing: water shortage is inevitable. With this hypothesis, it becomes clear that predictions have to be made in order to get ready, with new ways of water management, improvements or just correcting the mistakes of the past, before the moment when clean water becomes scarce.

Objectives

The main objective of this thesis was the rainfall characterization of a catchment area in Ensenada, Baja California, Mexico in order to enable future studies to dispose of necessary data for the predictions and water management.

In order to do that, the precipitation data from seventeen meteorological stations were obtained: Presa ELZ, Ejido Uruapan, El Álamo, El Ciprés, El Farito, Héroes de la Independencia, La Bocana, Maneadero, Ojos Negros, Olivares Mexicanos, Punta Banda, Real del Castillo, San Carlos, San Rafael, Santa Isabel, Santo Tomás and Sierra de Juárez.

Unfortunately, the data available for all of these stations was incomplete. Therefore, another objective made itself evident: in order to proceed with the characterization, it was necessary to restore the data in order to offer the best result of characterization possible.

For this, it was decided to test out if the multiple regression method, a rather simple and straightforward one, could be used in the restoration and if so how it would hold up. As a backup method of restoration the NIPALS method was considered.

Once the data was restored, the rainfall characterization was done in form of the Weibull distribution in order to obtain mean climate, extreme climate and the precipitation for given return periods.

After these parameters have been established and for further intent of characterization it was decided to establish the existence of a trend in the precipitations. That is, if over the years of now available data the precipitation has experienced a decrease or increase in its quantity through its seasons and months. To achieve these results, the Mann-Kendall trend test was applied for all the seventeen stations' mean and maximum values.

Finally, it was deemed of interest to establish a correlation, if any, there is between precipitation of those particular seventeen meteorological stations and the climate indexes, such as North Pacific climate index and the El Niño index. The El Niño was particularly interesting as this phenomenon has huge implications or agriculture, economics, etc.

El Niño is a climate cycle in the Pacific Ocean with a global impact on weather patterns. The cycle begins when warm water in the western tropical Pacific Ocean shifts eastward along the equator toward the coast of South America. Associated with it is a process called "coastal upwelling", or the rising of cold subsurface water that greatly affects the marine life.

In order to establish the correlation between the precipitation (the mean and maximum values for each meteorological station) and the climate indexes the cross-correlation technique was used.

Data

In order to be able to achieve the objectives of this thesis the following data was used:

- Precipitation data of the seventeen meteorological stations was obtained from Scientific Investigation and Higher Education Centre (CICESE in Spanish)
- The climate and El Niño indexes were obtained from Nacional Oceanic and Atmospheric Administration (NOAA) of U.S. Department of Commerce
 - o Eastern Tropical Pacific SST * (5N-5S,150W-90W) From NOAA Climate Prediction Centre (CPC) (Niño 3)
 - o Extreme Eastern Tropical Pacific SST *(0-10S, 90W-80W) From CPC (Niño 1+2)
 - o Central Tropical Pacific SST *(5N-5S) (160E-150W) From CPC (Niño 4)
 - o East Central Tropical Pacific SST *(5N-5S)(170-120W) From CPC (Niño 3.4)
 - o North Pacific patten is the area-weighted sea level pressure over the region 30N-65N, 160E-140W (NP)

Area of study

Situation and geography

The Baja California State is located in the northeast region of the Mexican Republic and in the septentrional part of the Peninsula of the same name. It is divided into 5 municipalities: Mexicali, the capital of the State, Tijuana, Tecate, Ensenada and Playas de Rosarito. The municipality of Ensenada (Figure 1) occupies 73.5% of the surface of the state, with a territorial extension of 52646.52 km² and is considered the biggest municipality in Mexico. The city and the port of Ensenada belongs to the municipality of the same name and it is the third most important city of the state with a population of 511772 residents (COPLADE, 2014).

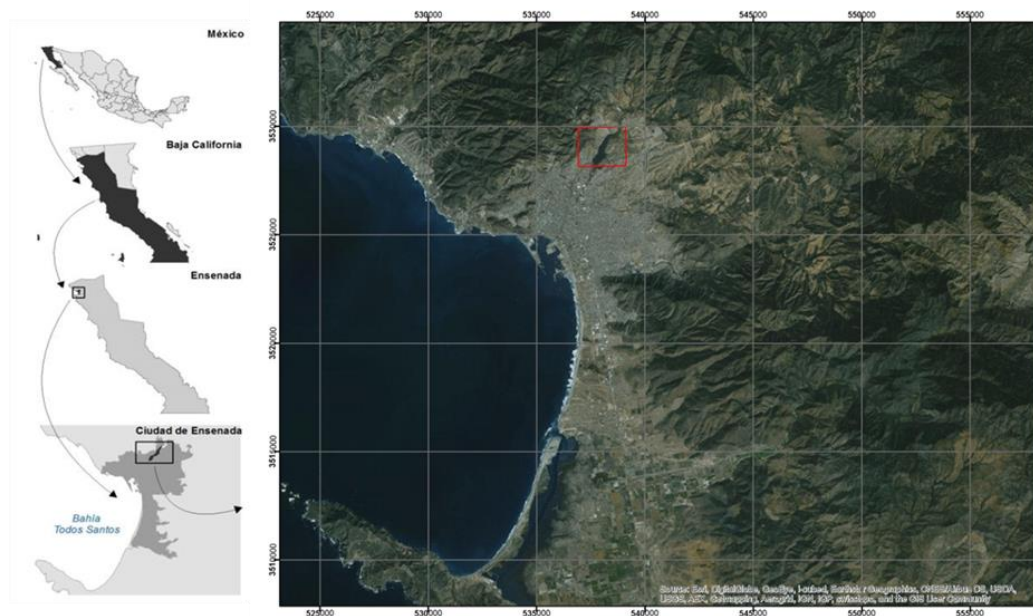


Figure 1 Ensenada geographical position. In red, Emilio López Zamora Dam.

Geology

The geological landscape of the municipality of Ensenada is relatively dominated by intrusive igneous formations (approximately 40% of the area), followed by extrusive igneous formations (33%), sedimentary rocks (20%) and metamorphic rocks (7%). Therefore, 73% of the territory is dominated by igneous rocks, which is the primary cause of nearly inexistent primary conductivity of water flux resulting from the scarce rainfall. Combined with the steep slopes of the area, streams of “abruptly variable flow” are originated when it rains and this, in turn, generates variability problems in riverbeds and causes flooding and erosion that affects agricultural valleys and cities close to the coast. The barrages found in the streams’ estuaries are formed by the sediment transportation and represent the rock formations of major importance from

hydrological point of view for their high permeability. This type of soil covers 2301 ha (55.34%) of the central area of population (IMIP, 2013).

Pedology

The majority of the soils in the municipality are azonal and underdeveloped: the soils with less than 60cm of depth represent approximately 80 % of the area of the total available soils and are grouped, according to FAO-UNESCO, 1971, classification, into the following types: regosols, lithosols and phaeozems. The soils with up to a meter depth represent approximately 15% of the total of the soils and are made up of the following types: yermosols, Solonchak, vertisols and fluvisols. Those that have more than a meter depth are the xerosols and represent 5% of the soils in the municipality (IIO-UABC, 2012).

Vegetation

The area has few forests and low vegetation density, a fact that reflects the aridity of the climate. The most predominant kind of vegetation is scrub, specifically the Sarcocaul type (8.25% of the surface), that occupies low hills and plateaus. It is associated with igneous rocks and shallow soils, such as regosols, lithosols and yermosols.

Climate

According to climate classification elaborated by Köppen and modified by Garcia (2004), the type of climate predominant in the area is that of Mediterranean semi-arid BSKs (e). The mean annual temperature oscillates between 14°C and 18°C with December and January being the coldest months and August and September the warmest. Winter is the period with the most rainfall.

Current use of soil

The current use of the soil in the area is dedicated to housing. The commercial use of soil is found in the first quadrant of the city and its vicinity. The rest is occupied by the commercial or mixed corridor.

Precipitation

The predominant rainfall pattern presents itself in winter, with a total annual mean of 266.5mm of rainfall. The rainy season takes place from December to March and tallies up to 75% of the annual rainfall. The rainiest months are January, February and March whether the driest ones are June and July.

Surficial Hydrology

The National Institute of Statistics, Geography and Informatics (INEGI in Spanish), the National Institute of Ecology (INE in Spanish) and the National Water Commission (CNA in Spanish) delineated Mexican watersheds at a scale of 1: 250000 from merely topographical and hydrographical (surface drainage network) criteria. The city of Ensenada is located within the Hydrologic Region 01 (RH01), called Baja California Northwest (Ensenada). It has an area of 26285 km². The RH01 region encompasses "C" Rio Tijuana - Arroyo Maneadero basin and Ensenada Bay subbasin with is 760 km² of area, is of an open type and drains into the sea. The surface water bodies of interest, Emilio López Zamora Dam and Arroyo Ensenada, are located within the sub-basin. The riverbeds within the subbasin remain dry or with very little water most of the year; it is only in rainy season when the riverbeds fill with water and can carry large amounts of fluid and sediment.

Emilio López Zamora (ELZ) Dam

The ELZ dam (Figure 1) is located at 31° 53' 45" north latitude and 116° 35' 49" west of Greenwich longitude, constructed over Arroyo Ensenada, 3.5 km northeast of the city of the same name, within the urban area on the border of the Colonia Popular 2 and Ejido Adolfo Ruiz Cortines. It began operating in 1978 in an unpopulated area on the outskirts of the city in order to control the flooding area. In the 1980s small ranches existed downstream of the curtain, outside the urban area. As a result of irregular growth of urbanization to the northwest sector, landowners sold their lands. Since 1981, when a treatment plant with 150l/s capacity was built, the ELZ dam is integrated in the water distribution network as a source of water supply for urban use. In 1985 two subdivisions were built, Villa Fontana and Green Valley located 100 and 400 meters downstream of the dam curtain respectively, adjacent to the Arroyo Ensenada shore, where the dam water is discharged.

The dam has a maximum capacity of 8.85 million of m³ and it is designed for a maximum consumption of 122m³/s and gives service to the 150km² of the catchment area.

Meteorological stations

In this thesis the meteorological stations database was obtained from Mexican National Meteorological Service (SMN in Spanish). This data constitutes daily observations gathered every 24 hours.

Table 1 shows the names of the stations and Figure 2 represents their positions.

Nº of the station	Name of the station
2014	El Álamo
2035	Ojos Negros
2036	Olivares Mexicanos
2045	San Carlos
2062	Santa Isabel
2065	Santo Tomás
2066	Sierra de Juárez
2072	Presa ELZ
2088	Héroes de la Independencia
2094	El Farito
2095	La Bocana
2104	El Ciprés
2106	Maneadero
2108	Punta Banda
2118	San Rafael
2122	Real del Castillo
2153	Ejido Uruapan

Table 1 Meteorological stations

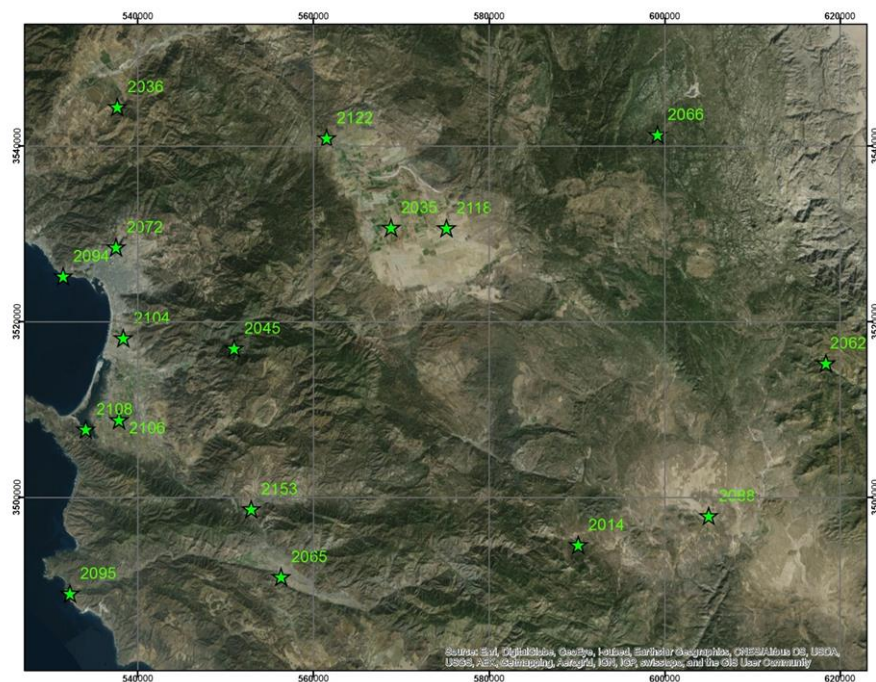


Figure 2 Position of the meteorological stations.

Methodology

Multiple regression

In order to restore the missing data, the multiple regression method was applied. It was chosen for its simplicity and straightforwardness, as it is a relatively simple tool within reach of everyone.

Multiple regression analysis is a powerful statistical tool used for predicting the unknown value of a variable from the known value of two or more variables, also called the predictors, by fitting a linear equation to observed data.

Every value of the independent variable X is associated with a value of the dependent variable Y . A linear transformation of the X variables is done so that the sum of squared deviations of the observed and predicted Y is a minimum. However, the computations take into account the interrelationships among all the variables and the weights assigned to them.

Formally, the model for the multiple linear regression, given n observations is:

$$y_i = \beta_0 + \beta_1 x_1 + e_i \quad [1]$$

$$i = 1, 2, 3 \dots n$$

Using the least squares method, the best fitting line can be found by minimizing the sum of the squares of the vertical distance from each data point on the line.

According to the multiple linear regression model the dependent variable is related to two or more independent variables. The general model for k variables is of the form

$$y_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \dots + \beta_k x_{ik} + e_i \quad [2]$$

$$i = 1, 2, 3 \dots n$$

The simple linear regression model is used to find the straight line that best fits the data. On the other hand, the multiple linear regression model, for example with two independent variables, is used to find the *plane* that best fits the data. Models that involve more than two independent variables are more complex in structure but can still be analysed using multiple linear regression techniques.

For linear regression analysis, a least-squares (LS) method is used to fit the linear regression model to the sample data, minimizing the goodness-of-fit profile and providing unbiased, minimum variance estimators for the parameters β_0 and β_1 .

The least-squares (LS) fit of the linear regression model estimates the parameters β_0 and β_1 by minimizing the sum of squared residuals, the goodness-of-fit profile (Hilborn and Mangel, 1997).

$$GOF = \sum_{i=1}^n (y_i - (\beta_0 + \beta_1 x_i))^2 = \sum_{i=1}^n e_i^2 \quad [3]$$

Taking partial derivatives of the GOF profile with respect to the unknown parameters β_0 and β_1 and setting these partial derivatives equal to 0, the solution for the parameter estimators is obtained with the normal equations

$$\hat{\beta} = \frac{\sum_{i=1}^n (x_i - \bar{x}) \cdot (y_i - \bar{y})}{\sum_{i=1}^n (x_i - \bar{x}) \cdot (x_i - \bar{x})} = \frac{SP_{xy}}{SS_x} \quad [4]$$

$$\hat{\beta} = \bar{y} - \hat{\beta}_1 \cdot \bar{x} \quad [5]$$

The second equation can also be obtained from the fact that the mean average or centroid (\bar{x}, \bar{y}) of the x and y sample values falls on the regression line. Estimators for the standard errors of $\hat{\beta}_1$ and $\hat{\beta}_0$ are given by

$$se_{\hat{\beta}_1} = \hat{\sigma} \cdot \sqrt{\frac{1}{(n-1) \cdot s_x^2}} \quad [6]$$

$$se_{\hat{\beta}_0} = \hat{\sigma} \cdot \sqrt{\frac{1}{n} + \frac{\bar{x}^2}{(n-1) \cdot s_x^2}} \quad [7]$$

where the estimator for the standard deviation of the residual error, the residual standard error, $\hat{\sigma} = s_{y|x}$, is

$$\hat{\sigma} = \sqrt{\frac{GOF}{n-2}} = \sqrt{\frac{\sum_{i=1}^n (y_i - (\beta_0 + \beta_1 x_i))^2}{n-2}} = \sqrt{\frac{\sum_{i=1}^n e_i^2}{n-2}} = s_{y|x} \quad [8]$$

The estimators for $\hat{\beta}_1$ and $\hat{\beta}_0$ are BLUE (the best linear unbiased estimators); that is, they are unbiased estimators of minimum variance.

Similarly, for multiple linear regression analysis, a LS method is used to fit the multiple linear regression model to sample data, minimizing the goodness-of-fit profile and providing unbiased, minimum variance estimators for the parameters, $\beta_0, \beta_1, \dots, \beta_p$.

Assessing the equality of variances

In order to decide if the variables in the formula for restoration given by the multiple regression method were valid to use, the Fisher's F-test was applied.

The F-test is designed to test if two population variances are equal. It does this by comparing the ratio of two variances [9]. So, if the variances are equal, the ratio of the variances will be 1.

$$F = \frac{s_1^2}{s_2^2} \quad [9]$$

All hypothesis testing is done under the assumption the null hypothesis is true. If the null hypothesis is true, then the F test-statistic given above can be simplified (dramatically). This ratio of sample variances will be test statistic used. If the null hypothesis is false, then we will reject the null hypothesis that the ratio was equal to 1 and our assumption that they were equal.

Used for validating the formulas obtained from the multiple regression method, it indicates the percentage of risk of introducing a significant amount of information to the model.

NIPALS

As a secondary solution for those cases where the multiple regression method would not be possible to execute, the NIPALS algorithm was considered.

The NIPALS (Nonlinear Iterative Partial Least Squares) algorithm is a Jacobi-like iterative method used to estimate the elements of the principal component analysis of a finite dimensional random vector. It is interesting to note that, due to the duality between the principal factors and the principal components, this algorithm can be adapted for datasets with missing data (Tenenhaus, 1998). In this context, NIPALS provides not only an estimation of principal factors and components, but also, by the mean of the data reconstitution formula, an imputation method for missing data.

The NIPALS algorithm in the multivariate finite dimensional case is seen as follows.

Let $X = (X_1, X_2, \dots, X_p)'$ be a random vector of dimension p , $p \geq 1$, such that $E(X_i) = 0$, $\forall i \in 1, p$. The expansion of the vector X in terms of principal components and principal factors is a well-known result in multivariate data analysis (Escoufier, 1970)

$$X = \sum_{h=1}^q \xi_h u_h \quad [10]$$

where $q = \dim L_2(X)$ and $\{\xi_h\}_{h=1,\dots,q}$, respectively $\{u_h\}_{h=1,\dots,q}$, are the principal components (random variables), respectively the principal factors (vectors in R^p) of the principal component analysis of X .

If only the first r components are used in [9], $r < q$, the approximation of order r of X is obtained by

$$\hat{X}^{(r)} = \sum_{h=1}^q \xi_h u_h \quad [11]$$

and, for each $i \in 1, \dots, p$,

$$\hat{X}_i^{(r)} = \sum_{h=1}^q \xi_h u_h(i) \quad [12]$$

The main idea of the NIPALS algorithm consists in the fact that for each $h = 1, \dots, q$, $u_h(i)$ represents the slope coefficient in the linear regression of the variable X_i on the component ξ_h . In the same way, if ω is an element of Ω , $\forall h = 1, \dots, q$, $\xi_h(\omega)$ represents the slope coefficient in the linear regression of the “variable” $(X_1(\omega), X_2(\omega), \dots, X_p(\omega))$ on the “variable” u_h (considered as elements of R^p).

The input data of the NIPALS algorithm are N independent realizations of the random vector X , $N \geq 1$, as a $N \times p$ matrix with entries $x(i, j)$, $i = 1, \dots, N$, $j = 1, \dots, p$. The assumption is that each column of the matrix is centred. The output is represented by N independent realizations of the q principal components and an estimate for the q principal factors.

The NIPALS algorithm:

- 1) $X_0 = X$
- 2) For $h = 1, 2, \dots, q$,
 - 2.1) $\xi_h = X_{h-1}(\cdot, 1)$ (the first column of X_{h-1});
 - 2.2) Repeat until convergence of u_h ,
 - 2.2.1) for $i = 1, 2, \dots, p$,

$$u_h(i) = \frac{\sum_{j: x(j,i); \xi_h(j) \text{ exist}} x_{h-1}(j, i) \xi_h(j)}{\sum_{j: x(j,i); \xi_h(j) \text{ exist}} \xi_h^2(j)} \quad [13]$$

2.2.2) Normalize u_h ;

2.2.3) For $i = 1, 2, \dots, N$,

$$\xi_h(i) = \frac{\sum_{j: x(i,j) \text{ exist}} x_{h-1}(i, j) u_h(j)}{\sum_{j: x(i,j) \text{ exist}} u_h^2(j)} \quad [14]$$

2.3) $X_h = X_{h-1} - \xi_h u_h'$

If there are no missing data, the NIPALS algorithm is equivalent to the SVD Jacobi algorithm for which the convergence is well known (Golub and Van Loan, 1996). In presence of missing data

at random, the quality of NIPALS algorithm depends of several parameters, the most important being the distribution of X , the degree of linear dependence between the X_i 's and the size of N with respect to p (Preda and Duhamel, 2005).

If $\{\hat{\xi}_h\}_{h=1,\dots,q}$ and $\{\hat{u}_h\}_{h=1,\dots,q}$ are the approximations of $\{\xi_h\}_{h=1,\dots,q}$ and $\{u_h\}_{h=1,\dots,q}$ provided by NIPALS, then $x(i, j)$ can be approximated by

$$\hat{x}(i, j) = \sum_{h=1}^q \hat{\xi}_h(i) \hat{u}_h(j) \quad [15]$$

This explicit formula [15] defines also the approximation for missing data by the NIPALS algorithm. Notice that if the PCA is carried out with a particular metric $M = TT'$, then NIPALS is applied to the matrix XT' .

Weibull distribution

Weibull (1951) derived the generalization of the exponential distribution that now bears his name. Since that time, the Weibull distribution has proved to be a successful model for many product failure mechanisms because it is a flexible distribution (given that it can, for example, take the form of either the exponential distribution or the approximate normal distribution, and can be skewed either positively or negatively), with a wide variety of possible failure rate curve shapes. However, Lloyd (1967), Ku et al. (1972), Hammitt (2004), and McCool (1998), among others, have extended the use of the Weibull distribution to other branches of statistics, such as reliability, risks, and quality control work. A distribution with a general probability density function (pdf) of

$$f(x) = \frac{C}{B} \left(\frac{x-A}{B} \right)^{C-1} \exp \left(- \left(\frac{x-A}{B} \right)^C \right) \quad [16]$$

known as a 3-parameter Weibull distribution. Its cumulative distribution function $F(x)$ and quantile function $x(F)$ are defined as

$$F(x) = 1 - \exp \left(- \left(\frac{x-A}{B} \right)^C \right) \quad 17$$

and

$$x(F) = B \left(-\ln(1 - F(x)) \right)^{1/C} + A \quad [18]$$

respectively. The parameters A , B and C determine the location, scale and shape of the distribution, respectively. For example, if we set the shape parameter $C = 1$ and the location parameter $A = 0$, the distribution changes its shape (say from skewed when $C = 1.5$ to exponential). The location for the two-parameter Weibull distribution is simply at the origin, i.e., $A = 0$.

Fitting Weibull distribution to data

For the extreme climate, the A, B and C Weibull parameters were calculated using the method of moments, as it is a robust method known and used for more than a 100 years (Stigler, 1986).

Method of moments estimation devises an estimator by insisting that a moment expectation that is true in the population holds true exactly for the corresponding moment within a given sample. That is, the method of moments insists that something true on average of the disturbances in the population be true on average about the residuals in any one sample.

The method of moments estimators is consistent. Thus, if the data generating process (DGP) satisfies the conditions for the Law of Large Numbers, the method of moments estimators tend to coincide with the true parameter values as the sample size grows without bound. In general, method of moments estimators are consistent whenever the Law of Large Numbers ensures that the sample moments in the DGP converge in probability to the corresponding population moments.

The generalized method of moments provides an estimation strategy when the number of restricted moments in the DGP exceeds the number of parameters to be estimated. Rather than satisfy one moment condition and violate another, the generalized method of moments (GMM) strategy chooses an estimator that balances each population moment condition against the others, seeking residuals that trade off violations of one moment restriction against violations of the other moment restrictions. A GMM estimator may satisfy no one moment condition, but it may come close to satisfying them all.

GMM does not guarantee an efficient estimator, but it does provide a consistent estimator, and its weighting scheme is more efficient than the simpler unweighted scheme. GMM provides a powerful tool for finding consistent estimators in models that are otherwise mathematically quite cumbersome.

Least square adjustment

In order to obtain B and C parameters (A parameter being 0) for medium climate, the least square adjustment was used.

Seen as a precursor to Generalized Moments Method, the least square adjustment minimizes three error types: error rate, relative error and RMSE.

$$ER = Mean\left(\frac{\sum_1^N |vm - ve|}{\sum_1^N vm}\right) \quad [19]$$

$$RE = \frac{\sqrt{\sum_1^N ((vm - ve)^2)}}{N} \quad [20]$$

$$RMSE = \sqrt{\frac{\sum_1^N ((vm - ve)^2)}{N}} \quad [21]$$

Hypothesis test

In order to verify the goodness of fit of A, B and C parameters for Weibull distribution, the Kolmogorov-Smirnov test was run.

The Kolmogorov-Smirnov goodness of fit test is an exact non-parametric test based on the maximum distance between a theoretical distribution function (entirely determined by the known values of its parameters) and the empirical distribution function of the sample. This test can only be used for continuous distributions.

When a parameter estimation precedes the goodness of fit test, the Kolmogorov-Smirnov test is not correct as the parameters are estimated by trying to bring the theoretical distribution as close as possible to the data. If it confirms the goodness of fit hypothesis, the Kolmogorov-Smirnov test risks being optimistic.

The Kolmogorov-Smirnov test compares two distributions. This test is used for distribution fitting tests for comparing an empirical distribution determined from a sample with a known distribution. It can also be used for comparing two empirical distributions.

Note: this test enables the similarity of the distributions to be tested at the same time as their shape and position.

Take a sample S_1 comprising n_1 observations, with F_1 the corresponding empirical distribution function. Take a second sample S_2 comprising n_2 observations, with F_2 the corresponding empirical distribution function.

The null hypothesis of the Kolmogorov-Smirnov test is defined by:

$$H_0: F_1(x) = F_2(x) \quad [22]$$

The Kolmogorov statistic is given by:

$$D_1 = \sup |F_1(x) - F_2(x)| \quad [23]$$

D_1 is the maximum absolute difference between the two empirical distributions. Its value therefore lies between 0 (distributions perfectly identical) and 1 (separations perfectly separated). The alternative hypothesis associated with this statistic is:

$$H_a: \frac{F_1(x)}{F_2(x)} \quad [24]$$

The Smirnov statistics are defined by:

$$D_2 = \sup\{F1(x) - F2(x)\} \quad [25]$$

$$D_3 = \sup\{F1(x) - F2(x)\}$$

The alternative hypothesis associated with D_2 is:

$$H_a: F1(x) < F2(x) \quad [26]$$

The alternative hypothesis associated with D_3 is:

$$H_a: F1(x) > F2(x) \quad [27]$$

Nikiforov (1994) proposed an exact test method for the Kolmogorov-Smirnov on two samples. This method was used in this test for the three alternative hypotheses. This test also enables the supposed difference D between the distributions to be introduced. The value must be between 0 and 1.

Mann Kendall

The purpose of the Mann-Kendall (MK) test (Mann 1945, Kendall 1975, Gilbert 1987) is to statistically assess if there is a monotonic upward or downward trend of the variable of interest over time. A monotonic upward (downward) trend means that the variable consistently increases (decreases) through time, but the trend may or may not be linear. The MK test can be used in place of a parametric linear regression analysis, which can be used to test if the slope of the estimated linear regression line is different from zero. The regression analysis requires that the residuals from the fitted regression line be normally distributed; an assumption not required by the MK test, since the MK test is a non-parametric (distribution-free) test.

Hirsch, Slack and Smith (1982) indicate that the MK test is best viewed as an exploratory analysis and is most appropriately used to identify stations where changes are significant or of large magnitude and to quantify these findings.

The following assumptions underlie the MK test:

- When no trend is present, the measurements (observations or data) obtained over time are independent and identically distributed. The assumption of independence means that the observations are not serially correlated over time.
- The observations obtained over time are representative of the true conditions at sampling times.
- The sample collection, handling, and measurement methods provide unbiased and representative observations of the underlying populations over time.

There is no requirement that the measurements be normally distributed or that the trend, if present, is linear. The MK test can be computed if there are missing values and values below the one or more limits of detection (LD), but the performance of the test will be adversely affected by such events. The assumption of independence requires that the time between samples be sufficiently large so that there is no correlation between measurements collected at different times.

The computational procedure for the Mann Kendall test considers the time series of n data points and T_i and T_j as two subsets of data where $i = 1, 2, 3, \dots, n-1$ and $j = i+1, i+2, i+3, \dots, n$. The data values are evaluated as an ordered time series. Each data value is compared with all subsequent data values. If a data value from a later time period is higher than a data value from an earlier time period, the statistic S is incremented by 1. On the other hand, if the data value from a later time period is lower than a data value sampled earlier, S is decremented by 1. The net result of all such increments and decrements yields the final value of S .

The Mann-Kendall S Statistic is computed as follows:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^n \text{sign}(T_j - T_i) \quad [28]$$

$$\text{Sign}(T_j - T_i) = \begin{cases} 1 & \text{if } T_j - T_i > 0 \\ 0 & \text{if } T_j - T_i = 0 \\ -1 & \text{if } T_j - T_i < 0 \end{cases} \quad [29]$$

where T_j and T_i are the annual values in years j and i , $j > i$, respectively.

If $n < 10$, the value of $|S|$ is compared directly to the theoretical distribution of S derived by Mann and Kendall. The two tailed test is used. At certain probability level H_0 is rejected in favour of H_1 if the absolute value of S equals or exceeds a specified value $S_{\alpha/2}$, where $S_{\alpha/2}$ is the smallest S which has the probability less than $\alpha/2$ to appear in case of no trend. A positive (negative) value of S indicates an upward (downward) trend. For $n \geq 10$, the statistic S is approximately normally distributed with the mean and variance as follows:

$$E(S) = 0 \quad [30]$$

The variance (σ^2) for the S -statistic is defined by:

$$\sigma^2 = \frac{n(n-1)(2n+5) - \sum t_j(i)(i-1)(2i+5)}{18} \quad [31]$$

in which t_i denotes the number of ties to extent i . The summation term in the numerator is used only if the data series contains tied values. The standard test statistic Z_s is calculated as follows:

$$Z_s = \begin{cases} \frac{S-1}{\sigma} & \text{for } S > 0 \\ 0 & \text{for } S = 0 \\ \frac{S+1}{\sigma} & \text{for } S < 0 \end{cases} \quad [32]$$

The test statistic Z_s is used a measure of significance of trend. In fact, this test statistic is used to test the null hypothesis, H_0 . If $|Z_s|$ is greater than $Z_{\alpha/2}$, where α represents the chosen significance level, then the null hypothesis is invalid implying that the trend is significant.

Another statistic obtained on running the Mann-Kendall test is Kendall's tau, which is a measure of correlation and therefore measures the strength of the relationship between the two variables. Kendall's tau is carried out on the ranks of the data. That is, for each variable separately, the values are put in order and numbered, 1 for the lowest value, 2 for the next lowest and so on.

In time series analysis it is essential to consider autocorrelation or serial correlation, defined as the correlation of a variable with itself over successive time intervals, prior to testing for trends. Autocorrelation increases the chances of detecting significant trends even if they are absent and vice versa. In order to consider the effect of autocorrelation, Hamed and Rao (1998) suggest a modified Mann-Kendall test, which calculates the autocorrelation between the ranks of the data after removing the apparent trend. The adjusted variance is given by:

$$Var[S] = \frac{1}{18} [N(N-1)(2N+5)] \frac{N}{NS^*} \quad [33]$$

Where

$$\frac{N}{NS^*} = 1 + \frac{2}{N(N-1)(N-2)} \sum_{i=1}^p (N-i)(N-i-1)(N-i-2)p_s(i) \quad [34]$$

N is the number of observations in the sample, NS^* is the effective number of observations to account for autocorrelation in the data, $p_s(i)$ is the autocorrelation between ranks of the observations for lag i , and p is the maximum time lag under consideration.

Sen's slope

In order to assess how rapid the change is in seasonal and monthly trends, the Theil-Sen's slope was applied.

The slope of the line (m) is estimated as the median of all pairwise slopes between each pair of points in the data set (Theil, 1950; Sen, 1968). Each individual slope estimate (m_{ij}) for the line connecting the i^{th} and j^{th} data point is calculated by use of the equation [35].

$$m_{ij} = \frac{Y_j - Y_i}{X_j - X_i} \quad [35]$$

for $i=1$ to $n-1$ and $j=2$ to n .

The number of possible slopes between data pairs is calculated by use of the equation [36].

$$N_p = \frac{n(n-1)}{2} \quad [36]$$

After each slope is calculated, all the slope estimates (m_{ij}) are sorted and ranked from lowest to highest. Sorting is a computationally intensive process because each slope estimate in the array of slopes must be compared to other values and put in the proper order. If N_p is an odd number, the median slope is selected as the middle value of the array; otherwise, the median is calculated as the arithmetic average of the two centre points.

Pearson correlation

Pearson's correlation coefficient is a statistical measure of the strength of a linear relationship between paired data. In a sample it is denoted by r and is by design constrained as follows

$$-1 \leq r \leq 1$$

The formula for Pearson's correlation takes on many forms. A commonly used formula is shown below.

$$r = \frac{\sum XY - \frac{\sum X \sum Y}{N}}{\sqrt{(\sum X^2 - \frac{(\sum X)^2}{N})(\sum Y^2 - \frac{(\sum Y)^2}{N})}} \quad [37]$$

The result r gives information about the type of correlation: positive values denote positive linear correlation and negative values denote negative linear correlation. A value of 0 denotes no linear correlation. The closer the value is to 1 or -1 , the stronger the linear correlation.

Cross-correlation

Lagged correlation refers to the correlation between two-time series shifted in time relative to one another. Lagged correlation is important in studying the relationship between time series for two reasons. First, one series may have a delayed response to the other series, or perhaps a delayed response to a common stimulus that affects both series. Second, the response of one series to the other series or an outside stimulus may be “smeared” in time, such that a stimulus restricted to one observation elicits a response at multiple observations.

The cross-correlation function (ccf) of two-time series is the product-moment correlation as a function of lag, or time-offset, between the series. It is helpful to begin defining the ccf with a definition of the cross-covariance function (ccvf). Consider N pairs of observations on two time series, u_t and y_t . Following Chatfield (2004), the sample ccvf is given by

$$c_{uy}(k) = \frac{1}{N} \sum_{t=1}^{N-k} (u_t - \bar{u})(y_{t+k} - \bar{y}) \quad [38]$$

$$[k = 0, 1, \dots, (N - 1)]$$

$$c_{uy}(k) = \frac{1}{N} \sum_{t=1-k}^{N-k} (u_t - \bar{u})(y_{t+k} - \bar{y}) \quad [39]$$

$$[k = -1, -2, \dots, -(N - 1)]$$

where N is the series length, \bar{u} and \bar{y} are the sample means, and k is the lag. The sample cross-correlation function (ccf) is the ccvf scaled by the variances of the two series:

$$r_{uy}(k) = \frac{c_{uy}(k)}{\sqrt{c_{uu}(0)c_{yy}(0)}} \quad [40]$$

Where $c_{uu}(0)$ and $c_y(0)$ and are the sample variances of u_t and y_t .

The ccvf and ccf are asymmetrical functions. The asymmetry brings about the need for the two equations: [38] and [39]. The cross-correlation function as described by equations [38] and [36] can be described in terms of “lead” and “lag” relationships. The equation [38] applies to y_t shifted forward relative to u_t . With this direction of shift, u_t is said to “lead” y_t . This is equivalent to saying that y_t “lags” u_t . The equation [39] describes the reverse situation, and summarizes lagged correlations when y_t “leads” u_t (u_t “lags” y_t).

Autocorrelation

Autocorrelation is a measure of the dependence of time series values at a certain time on the values at another time. It is the Pearson correlation between all the pairs of points in the time series with a given separation in time or lag. Positively autocorrelated series are sometimes referred to as persistent because high values tend to follow high values and low values tend to follow low values. Negatively autocorrelated series are characterized by reversals from high to low values from one-time segment to the next, and vice versa.

Autocorrelation functions of deterministic data (like sine wave) persist over all time displacements, whereas autocorrelation functions of stochastic processes tend to zero for large time displacement (for zero-mean time series).

The first order correlation (i.e. lag = 1) is the correlation coefficient of the first $N - 1$ observations [x_t : $t = 1, 2, \dots, N - 1$] and the next $N - 1$ observations [x_t : $t = 2, 3, \dots, N$]. It is given by the following formula:

$$r_1 = \frac{\sum_{t=1}^{N-1} (x_t - \bar{x}_1)(x_{t+1} - \bar{x}_2)}{\sqrt{\sum_{t=1}^{N-1} (x_t - \bar{x}_1)^2} \sqrt{\sum_{t=1}^{N-1} (x_{t+1} - \bar{x}_2)^2}} \quad [41]$$

Where \bar{x}_1 is the mean of the first $N-1$ observations, and \bar{x}_2 is the mean of the last $N-1$ observations.

For reasonably large N , the difference between \bar{x}_1 and \bar{x}_2 would be negligible, and r_1 can be approximated by:

$$r_1 = \frac{\sum_{t=1}^{N-1} (x_t - \bar{x})(x_{t+1} - \bar{x})}{\sum_{t=1}^N (x_t - \bar{x})^2} \quad [42]$$

Where $\bar{x} = \frac{1}{N} \sum_{t=1}^N x_t$ is the overall mean.

Equation [42] can be generalized for computing the correlation between observations separated by k time units:

$$r_k = \frac{\sum_{t=1}^{N-k} (x_t - \bar{x})(x_{t+k} - \bar{x})}{\sum_{t=1}^N (x_t - \bar{x})^2} \quad [43]$$

The array of autocorrelation coefficients r_k provides crucial information about the internal structure of the time series. The plot with k as abscissa and r_k as ordinate is called correlogram.

The standard error of autocorrelation for lag k is computed by the following formula:

$$SE_k = \sqrt{\frac{1}{N} \sum_{i=1}^k r_i^2} \quad [44]$$

The value of the autocorrelation function at lag 0 is always equal to 1. The horizontal band about zero represents the approximate 95% confidence limits for $H_0: \rho = 0$. If no autocorrelation estimate falls outside the strip defined by the two dotted lines, and the data contain no outliers, one may safely assume that there is no serial correlation.

Results and discussion

Restored data

The data available for the geographical zone in question was obtained from CICESE webpage, studying 17 meteorological stations: Presa ELZ, Ejido Uruapan, El Álamo, El Ciprés, El Farito, Héroes de la Independencia, La Bocana, Maneadero, Ojos Negros, Olivares Mexicanos, Punta Banda, Real del Castillo, San Carlos, San Rafael, Santa Isabel, Santo Tomás and Sierra de Juárez. The daily precipitation data collection started on the 1st of January of 1923 ending on the 30th of November 2008. Unfortunately, up until the 1st of January of 1949 only three stations had somewhat available data. Namely, Presa ELZ, El Álamo and Ojos Negros. And these numbers at hand also presented numerous gaps, that spanned up to two years. Therefore, the decision was made to start the data restoration starting 1st of January 1949. So the total time span was comprised of 21884 days, i.e. 21884 total observations.

Table 2 offers summary statistics describing the original situation, the moment prior to any kind of restoration and data treatment.

Variable	Mean	Maximum	Standard deviation	Observations with missing data	Observations without missing data
Presa ELZ	0.706	81.5	3.644	4919	26462
Ejido Uruapan	0.816	111	4.713	22386	8995
El Álamo	0.843	123	4.481	15234	16147
El Ciprés	0.581	64	3.152	21651	9730
El Farito	0.756	50	3.657	29370	2011
Héroes de la Independencia	0.827	88.6	4.31	23777	7604
La Bocana	0.92	62	4.286	26233	5148
Maneadero	0.674	70	3.488	22400	8981
Ojos Negros	0.634	85	3.189	16156	15225
Olivares Mexicanos	0.839	107	4.384	14802	16579
Punta Banda	0.768	150	4.676	21545	9836
Real del Castillo	0.768	60	4.004	27773	3608
San Carlos	0.857	93	4.355	18777	12604
San Rafael	0.827	203	5.248	26314	5067
Santa Isabel	1.062	76.2	4.709	27644	3737
Santo Tomás	0.729	98	3.944	9716	21665
Sierra de Juárez	1.115	97	4.981	22727	8654

Table 2 Summary statistics for original data

Speaking in percentages, the missing data is distributed as shown in table 3.

Variable	% of missing data
Presa ELZ	11.62
Ejido Uruapan	58.90
El Álamo	27.06
El Ciprés	55.54
El Farito	90.81
Héroes de la Independencia	65.25
La Bocana	76.48
Maneadero	58.96
Ojos Negros	31.35
Olivares Mexicanos	24.24
Punta Banda	55.05
Real del Castillo	83.51
San Carlos	42.41
San Rafael	76.85
Santa Isabel	82.92
Santo Tomás	2.28
Sierra de Juárez	60.46

Table 3 Percentage of missing data

Seeing that the Santo Tomás station had the lowest percentage of missing data, the decision was made to start the data restoration with this station, implementing the multiple regression method.

The process of the implementation took into account the various segments of the stations with available data in the relation to the Santo Tomás station's missing data. The various resulting formulas were compared and the one with the highest R^2 was chosen to reconstruct the missing figures whenever the non-missing data was available.

Once the Santo Tomás station was restored completely, the next station with the smallest percentage of missing data, Presa ELZ, was restored following the same criteria.

For each formula the F Fisher was considered as an indicator of risking incorrect data usage. Those formulas where F had a value higher than 0.0001 were not considered for use for restoration.

Overall, the restoration of each station was adaptable to the data available in each segment of missing data. That is, whenever there was a figure at hand, an actual value of precipitation, measured or already restored beforehand, the formulas for restoration were adapted to the available data.

As an example tables 4 and 5 present the order that the restoration took.

Santo Tomás

Equation	R ²
$\text{Santo Tomás} = 0.11598 + 0.15548\text{Presa ELZ} \\ + 0.38110\text{Ejido Uruapan} + 0.16905\text{La Bocana} \\ + 0.19038\text{Real del Castillo}$	0.8749
$\text{Santo Tomás} = 0.13938 + 0.32232\text{Presa ELZ} \\ + 0.55910\text{Ejido Uruapan}$	0.8533
$\text{Santo Tomás} = 0.00272 + 0.08404\text{Presa ELZ} \\ + 0.05592\text{Héroes de la Independencia} \\ + 0.31225\text{La Bocana} + 0.02223\text{Maneadero} \\ + 0.23430\text{Ojos Negros} + 0.25956\text{Punta Banda} \\ + 0.14067\text{San Carlos}$	0.8529
$\text{Santo Tomás} = 0.03952 - 0.02282\text{Presa ELZ} \\ + 0.14377\text{El Álamo} + 0.36275\text{La Bocana} \\ + 0.19907\text{Ojos Negros} \\ + 0.06751\text{Olivares Mexicanos} \\ + 0.16820\text{Punta Banda} \\ + 0.11334\text{Real del Castillo}$	0.7968
$\text{Santo Tomás} = -0.02334 + 0.21677\text{Presa ELZ} \\ + 0.15497\text{El Álamo} + 0.13942\text{Ojos Negros} \\ + 0.16442\text{Olivares Mexicanos} \\ + 0.23755\text{San Carlos} + 0.01911\text{Sierra de Juárez}$	0.7742
$\text{Santo Tomás} = 0.04735 + 0.03563\text{Presa ELZ} \\ + 0.12722\text{El Álamo} + 0.40537\text{La Bocana} \\ + 0.20169\text{Ojos Negros} \\ + 0.10109\text{Olivares Mexicanos} \\ + 0.12058\text{Real del Castillo}$	0.7732
$\text{Santo Tomás} = 0.07991 + 0.28418\text{Presa ELZ} \\ + 0.09326\text{El Ciprés} + 0.17534\text{Maneadero} \\ + 0.19311\text{Punta Banda} + 0.24598\text{San Carlos}$	0.7727
$\text{Santo Tomás} = 0.06756 + 0.43413\text{Presa ELZ} \\ + 0.18595\text{El Álamo} + 0.00950\text{El Ciprés} \\ + 0.40309\text{Maneadero} + 0.09862\text{Punta Banda}$	0.7725

<i>Santo Tomás</i> = 0.06510 + 0.05856 <i>Presa ELZ</i> + 0.43181 <i>La Bocana</i> + 0.09408 <i>Maneadero</i> + 0.07021 <i>Ojos Negros</i> + 0.08235 <i>Olivares Mexicanos</i> + 0.22572 <i>Real del Castillo</i>	0.7714
<i>Santo Tomás</i> = 0.06412 + 0.09491 <i>Presa ELZ</i> + 0.45404 <i>La Bocana</i> + 0.09956 <i>Maneadero</i> + 0.10259 <i>Ojos Negros</i> + 0.22797 <i>Real del Castillo</i>	0.7687
<i>Santo Tomás</i> = 0.00033 + 0.40542 <i>Presa ELZ</i> + 0.13633 <i>El Álamo</i> + 0.24249 <i>Ojos Negros</i> + 0.17758 <i>Olivares Mexicanos</i>	0.7324
<i>Santo Tomás</i> = 0.09868 + 0.26982 <i>Ejido Uruapan</i> + 0.05350 <i>El Ciprés</i> + 0.29659 <i>Maneadero</i> + 0.14093 <i>Punta Banda</i> + 0.10383 <i>San Carlos</i>	0.7121
<i>Santo Tomás</i> = 0.09782 + 0.27525 <i>Ejido Uruapan</i> + 0.06676 <i>El Ciprés</i> + 0.40552 <i>Maneadero</i> + 0.12056 <i>San Carlos</i>	0.7055
<i>Santo Tomás</i> = 0.04674 + 0.20263 <i>Ejido Uruapan</i> + 0.04324 <i>El Ciprés</i> + 0.59326 <i>Maneadero</i> + 0.16461 <i>Olivares Mexicanos</i> + 0.11479 <i>Punta Banda</i>	0.6983
<i>Santo Tomás</i> = 0.11289 + 0.28404 <i>Ejido Uruapan</i> + 0.02931 <i>El Ciprés</i> + 0.51503 <i>Maneadero</i> + 0.14071 <i>Punta Banda</i>	0.6507
<i>Santo Tomás</i> = 0.12562 + 0.29615 <i>Ejido Uruapan</i> + 0.06221 <i>El Ciprés</i> + 0.60765 <i>Maneadero</i>	0.6366

Table 4 Restoration equations for Santo Tomás station

Presa ELZ

Formula	R ²
<i>Presa ELZ = 0.17304 – 0.54901Ojos Negros + 0.38375Olivares Mexicanos + 0.49954San Carlos + 0.37932Santo Tomás</i>	0.9008
<i>Presa ELZ = 0.07654 + 0.30036El Ciprés + 0.43757San Carlos + 0.25215Santo Tomás</i>	0.8803
<i>Presa ELZ = 0.09462 + 0.26689Olivares Mexicanos + 0.54068San Carlos</i>	0.8663
<i>Presa ELZ = 0.01388 – 0.01005El Álamo + 0.19742La Bocana + 0.22386Maneadero + 0.21033Ojos Negros + 0.21402Olivares Mexicanos + 0.19047Real del Castillo</i>	0.8291
<i>Presa ELZ = 0.03248 – 0.02760Ejido Uruapan + 0.19016El Álamo + 0.19044El Ciprés + 0.10428La Bocana + 0.38307Maneadero + 0.18416Santo Tomás</i>	0.8236
<i>Presa ELZ = –.0.00720 + 0.24533El Ciprés + 0.06758Héroes de Independencia + 0.10987Maneadero + 0.17532Punta Banda + 0.16225Santo Tomás</i>	0.8136
<i>Presa ELZ = 0.01596 + 0.15420Ejido Uruapan + 0.03420El Ciprés + 0.02084Héroes de la Independencia + 0.26266Maneadero + 0.31046Punta Banda + 0.20646Santo Tomás</i>	0.8076
<i>Presa ELZ = 0.03707 – 0.00778Ejido Uruapan + 0.17865El Álamo + 0.11202El Ciprés + 0.34720Maneadero + 0.06579Olivares Mexicanos + 0.07872Punta Banda + 0.21281Santo Tomás</i>	0.8043

$Presa\ ELZ = 0.02824 + 0.08501Ejido\ Uruapan$ $+ 0.13461El\ \acute{A}lamo + 0.07445El\ Cipr\acute{e}s$ $+ 0.30891Maneadero + 0.10772Punta\ Banda$ $+ 0.25591Santo\ Tom\acute{a}s$	0.7934
$Presa\ ELZ = 0.05526 + 0.07216Ejido\ Uruapan$ $+ 0.12907El\ \acute{A}lamo + 0.12510El\ Cipr\acute{e}s$ $+ 0.36032Maneadero + 0.30496Santo\ Tom\acute{a}s$	0.7730
$Presa\ ELZ = 0.04450 + 0.00395El\ \acute{A}lamo$ $+ 0.22388Ojos\ Negros$ $+ 0.35741Olivares\ Mexicanos$ $+ 0.31149Santo\ Tom\acute{a}s$	0.7721
$Presa\ ELZ = 0.03365 + 0.30025El\ Cipr\acute{e}s$ $+ 0.17790Maneadero$ $+ 0.21126Olivares\ Mexicanos$ $+ 0.06292Punta\ Banda + 0.27303Santo\ Tom\acute{a}s$	0.7701
$Presa\ ELZ = 0.00951 + 0.09400Ejido\ Uruapan$ $+ 0.15947El\ Cipr\acute{e}s$ $+ 0.10537H\acute{e}roes\ de\ la\ INdependencia$ $+ 0.22780Olivares\ Mexicanos$ $+ 0.27892Punta\ Banda + 0.14419Santo\ Tom\acute{a}s$	0.7651
$Presa\ ELZ = 0.04716 + 0.19508El\ Cipr\acute{e}s$ $+ 0.33143Maneadero + 0.15025Punta\ Banda$ $+ 0.35333Santo\ Tom\acute{a}s$	0.7423
$Presa\ ELZ = 0.04329 + 0.11946Ejido\ Uruapan$ $+ 0.14933El\ Cipr\acute{e}s + 0.41222Maneadero$ $+ 0.32912Santo\ Tom\acute{a}s$	0.7217
$Presa\ ELZ = 0.07591 + 0.15254Ejido\ Uruapan$ $+ 0.46593Maneadero + 0.30694Santo\ Tom\acute{a}s$	0.7097
$Presa\ ELZ = 0.08654 + 0.03265El\ \acute{A}lamo$ $+ 0.39116Ojos\ Negros + 0.47032Santo\ Tom\acute{a}s$	0.7018

Table 5 Restoration equations for Presa ELZ station

For the restoration process of all other meteorological stations, see Annex 1.

Once fifteen stations were restored, only the Santa Isabel station and the Sierra de Juárez station were left where a problem was encountered: the multiple regression method's formulas returned a R^2 inferior to 0.5. For these two stations the NIPALS method was used.

Taking into account the original and restored data the descriptive statistics are shown in table 6.

Variable	Mean	Maximum	Standard deviation
Presa	0.692	81.5	3.555
Ejido	0.818	234.6	4.615
El Álamo	0.837	123	4.474
El Ciprés	0.495	64	2.528
El Farito	0.466	56.5	2.479
Héroes de la Independencia	0.669	89.7	3.622
La Bocana	0.713	91.7	3.556
Maneadero	0.641	70	3.21
Ojos Negros	0.631	85	3.115
Olivares Mexicanos	0.808	107	4.199
Punta Banda	0.643	150	3.735
Real del Castillo	0.708	73.7	3.459
San Carlos	0.829	94.3	4.102
San Rafael	0.746	203	3.837
Santa Isabel	0.843	76.2	3.273
Santo Tomás	0.722	98	3.908
Sierra de Juárez	0.868	97	3.777

Table 6 Summary statistics for restored data

For a clearer comparison the following tables compares the comparative statistics between the original data and the restored data are shown in tables 7 to 9.

Station	Mean original data	Mean restored data
Presa ELZ	0.706	0.692
Ejido Uruapan	0.816	0.818
El Álamo	0.843	0.837
El Ciprés	0.581	0.495
El Farito	0.756	0.466
Héroes de la Independencia	0.827	0.669
La Bocana	0.92	0.713
Maneadero	0.674	0.641
Ojos Negros	0.634	0.631
Olivares Mexicanos	0.839	0.808
Punta Banda	0.768	0.643
Real del Castillo	0.768	0.708
San Carlos	0.857	0.829
San Rafael	0.827	0.746
Santa Isabel	1.062	0.843
Santo Tomás	0.729	0.722
Sierra de Juárez	1.115	0.868

Table 7 Mean values comparison between original and restored data

Station	Maximum original data	Maximum restored data
Presa ELZ	81.5	81.5
Ejido Uruapan	111	234.6
El Álamo	123	123
El Ciprés	64	64
El Farito	50	56.5
Héroes de la Independencia	88.6	89.7
La Bocana	62	91.7
Maneadero	70	70
Ojos Negros	85	85
Olivares Mexicanos	107	107
Punta Banda	150	150
Real del Castillo	60	73.7
San Carlos	93	94.3
San Rafael	203	203
Santa Isabel	76.2	76.2
Santo Tomás	98	98
Sierra de Juárez	97	97

Table 8 Maximum values comparison between original and restored data

Station	Standard deviation original data	Standard deviation restored data
Presa ELZ	3.644	3.555
Ejido Uruapan	4.713	4.615
El Álamo	4.481	4.474
El Ciprés	3.152	2.528
El Farito	3.657	2.479
Héroes de la Independencia	4.31	3.622
La Bocana	4.286	3.556
Maneadero	3.488	3.21
Ojos Negros	3.189	3.115
Olivares Mexicanos	4.384	4.199
Punta Banda	4.676	3.735
Real del Castillo	4.004	3.459
San Carlos	4.355	4.102
San Rafael	5.248	3.837
Santa Isabel	4.709	3.273
Santo Tomás	3.944	3.908
Sierra de Juárez	4.981	3.777

Table 9 Standard deviation values comparison between original and restored data

Comparing the descriptive statistics between the original and restored data, it may be observed that the numbers of the mean, maximum and standard deviation are very similar and vary very little. In case of Ejido Uruapan station, though, the maximum precipitation value increases more than double, but that may be due to the data used for restoration not equally distributed in time. That is, the data available originally spanned only a few number of years.

As stated above, the overall statistics don't change that much and at the first look the restoration that took place may be considered as valid.

Weibull distributions

In this chapter the Weibull distribution of the two sets of data will be discussed, which will further show the validity of restoration and will also provide the mean climate and extreme climate distributions.

The following graphs show the Weibull distribution for the 17 meteorological stations in the studied catchment area. Overall, the precipitation data is well adjusted to the Weibull distribution with some particularities which will be discussed further on.

In order to obtain the Weibull parameters A, B and C the method of moments was applied for the extreme climate characterization and the Least Square Adjustment for the mean climate.

For each meteorological station a table was created to show the adjusted parameters, number of valid data considered (important in the case of the original data, with gaps) and R^2 . Also, a

table of precipitation corresponding to a specific return period is presented in extreme climate case.

The Kolmogorov-Smirnov test was used to test the goodness of fit. Generally, the null hypothesis (the data follows Weibull distribution) was accepted. For the parameters and values see Annex 2.

As no confidence intervals or climate change tendencies were not considered, the precipitation values for the given return periods should be taken with caution. But should a need of an approximation of a value arise, the precipitation values given in this results could be safely used.

Extreme climate

Tables 10 to 60 show the probability of non-exceedance distribution and Weibull parameters for each station considering restored and original data and the precipitation values for a given return period.

Presa ELZ

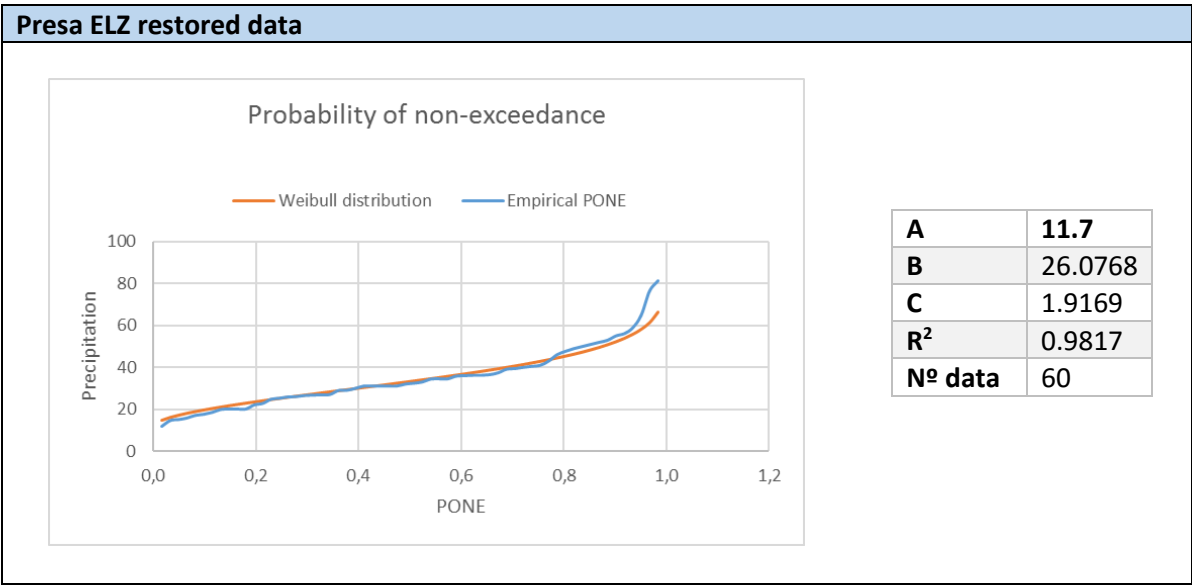
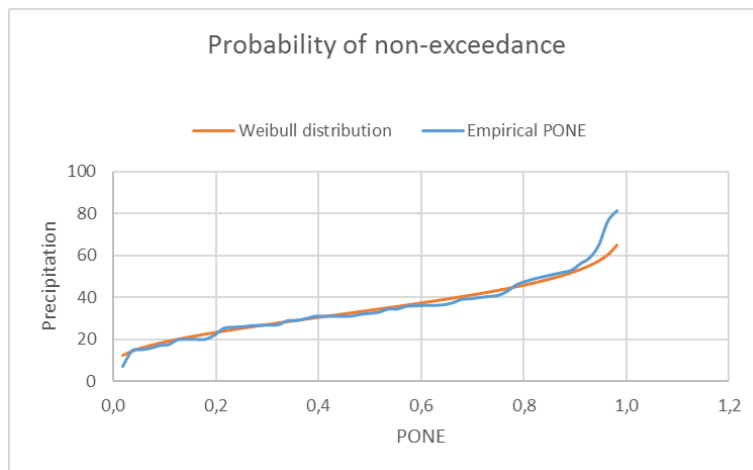


Table 10 Extreme climate probability of non-exceedance distribution and Weibull parameters for Presa ELZ station restored data

Presa ELZ original data


A	7
B	31.7083
C	2.3003
R²	0.9684
Nº data	55

Table 11 Extreme climate probability of non-exceedance distribution and Weibull parameters for Presa ELZ station original data

Return period (years)	P restored data (mm)	P original data (mm)
1	11.7	7
5	45.13	46.00
10	51.99	52.57
25	59.69	59.71
50	64.83	64.37
75	67.63	66.89
100	69.54	68.59
150	72.15	70.89
250	75.29	73.65
300	76.37	74.59
400	78.06	76.05
500	79.33	77.16

Table 12 Precipitation for Presa ELZ station given a return period

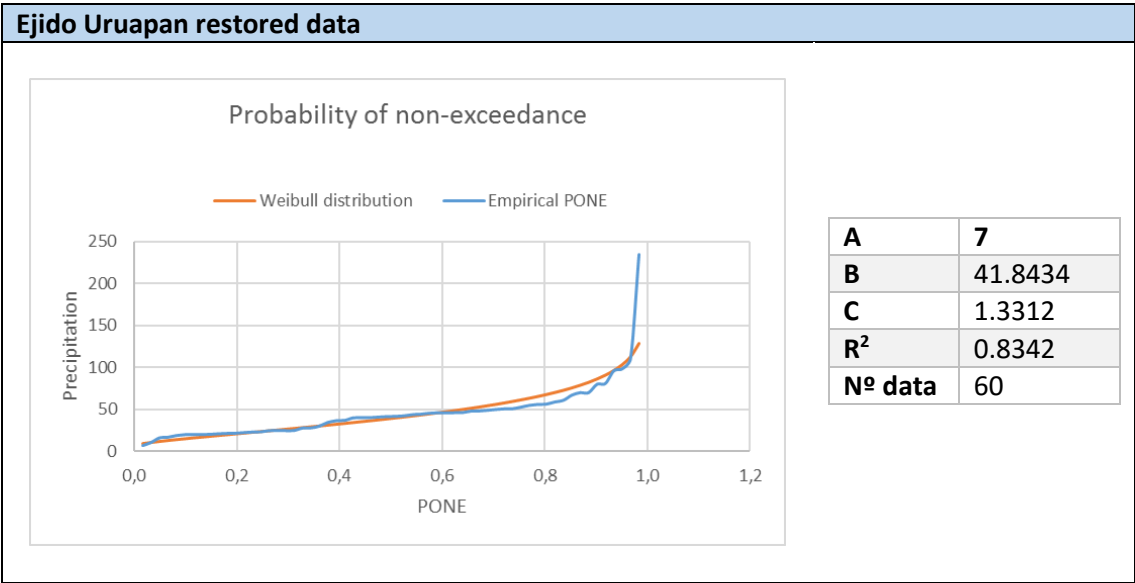


Table 13 Extreme climate probability of non-exceedance distribution and Weibull parameters for Ejido Uruapan station restored data

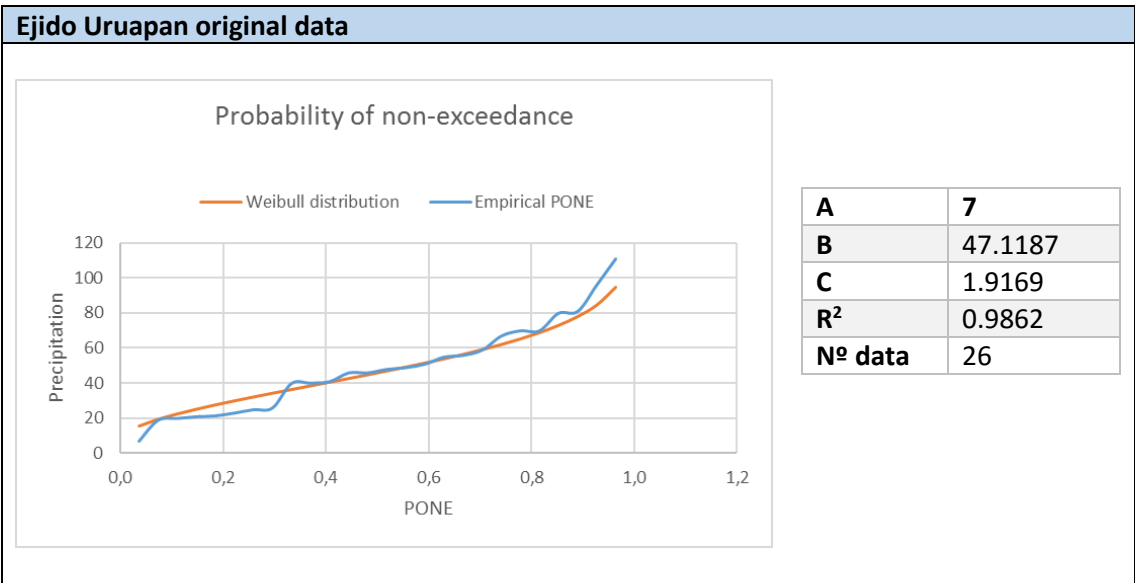


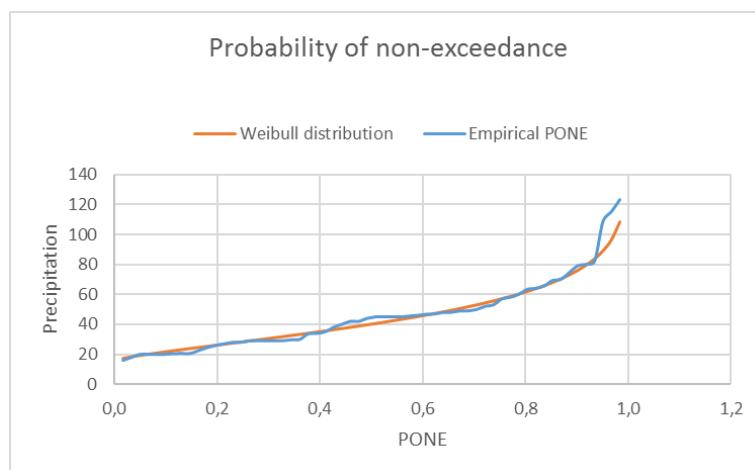
Table 14 Extreme climate probability of non-exceedance distribution and Weibull parameters for Ejido Uruapan station original data

Return period (years)	P restored data (mm)	P original data(mm)
1	7	7
5	66.83	67.4
10	85.29	79.8
25	107.7	93.71
50	123.59	102.99
75	132.55	108.06
100	138.79	111.52
150	147.41	116.22
250	158.03	121.90
300	161.76	123.86
400	167.59	126.90
500	172.07	129.21

Table 15 Precipitation for Ejido Uruapan station given a return period

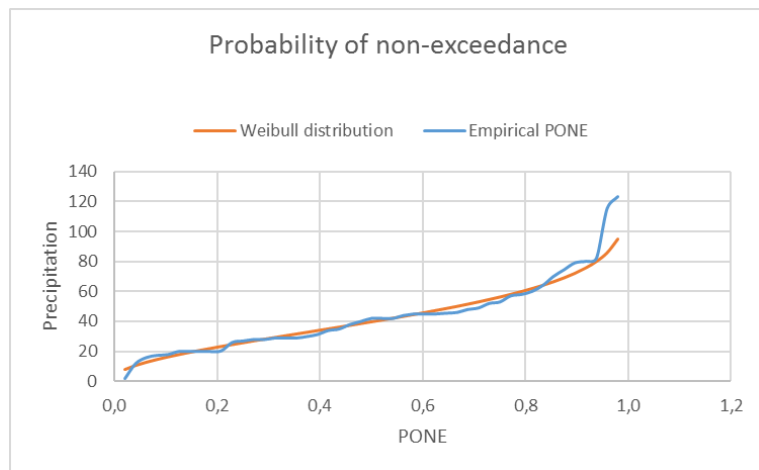
El Álamo

El Álamo restored data



A	16
B	32.0556
C	1.3312
R²	0.9817
Nº data	60

Table 16 Extreme climate probability of non-exceedance distribution and Weibull parameters for El Álamo station restored data

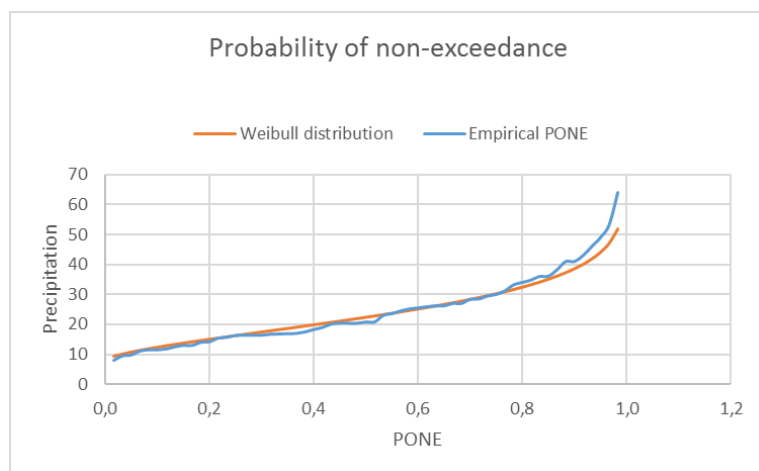
El Álamo with original data

A	2
B	46.0346
C	1.9169
R²	0.9588
Nº data	47

Table 17 Extreme climate probability of non-exceedance distribution and Weibull parameters for El Álamo station original data

Return period (years)	P restored data (mm)	P original data (mm)
1	16	2
5	61.83	61.01
10	75.98	73.13
25	93.14	86.71
50	105.32	95.78
75	112.18	100.74
100	116.96	104.11
150	123.57	108.71
250	131.70	114.25
300	134.56	116.17
400	139.03	119.14
500	142.45	121.40

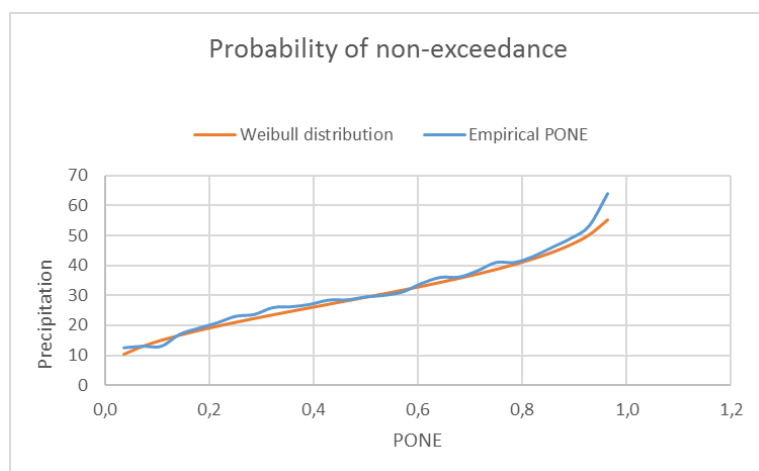
Table 18 Precipitation for El Álamo station given a return period

*El Ciprés***El Ciprés restored data**

A	8
B	18.1606
C	1.5974
R2	0.9920
Nº data	59

Table 19 Extreme climate probability of non-exceedance distribution and Weibull parameters for El Ciprés station restored data

This meteorological station has a peculiarity that is not found in other restored stations: according to the restoration, the year 2006 did not register any precipitation. This fact may be due to poor data recollection by the pluviometer or the fact that the other stations, from which the restoration took place, did not have enough data to properly restore the values for this particular year. On the other hand, it also may serve to demonstrate the area's arid climate that does contemplate occasional yearly lack of precipitation. Seeing the situation and given the fact that this is the only station with this kind of setback, the data for the year 2006 has been discarded for better Weibull adjustment properties.

El Ciprés original data

A	3
B	31.0246
C	2.3003
R2	0.9891
Nº data	27

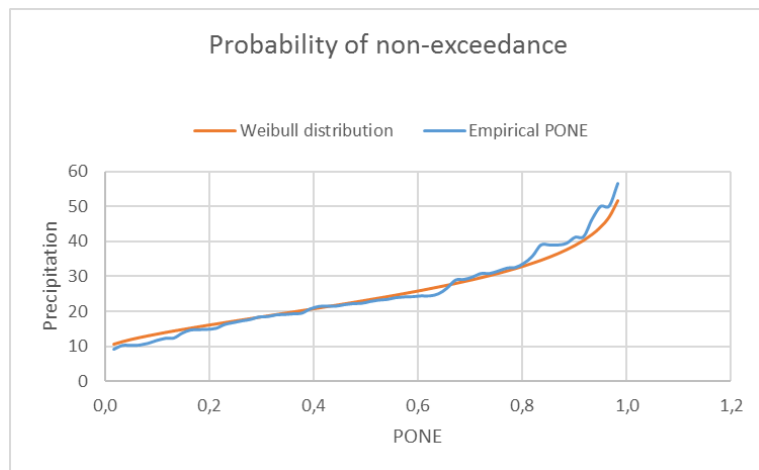
Table 20 Extreme climate probability of non-exceedance distribution and Weibull parameters for El Ciprés station original data

Return period (years)	P restored data (mm)	P original data (mm)
1	8	3
5	32.46	41.16
10	38.61	47.58
25	45.75	54.57
50	50.66	59.14
75	63.37	61.60
100	55.24	63.26
150	57.81	65.51
250	60.93	68.21
300	62.01	69.14
400	63.70	70.57
500	64.99	71.65

Table 21 Precipitation for El Ciprés station given a return period

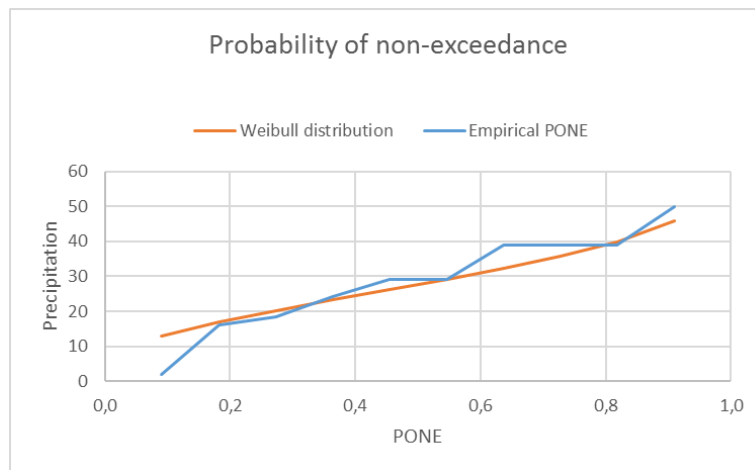
El Farito

El Farito restored data



A	9.3
B	17.4806
C	1.5974
R²	0.9920
Nº data	60

Table 22 Extreme climate probability of non-exceedance distribution and Weibull parameters for El Farito station restored data

El Farito original data


A	2
B	30.0141
C	2.3003
R²	0.9312
Nº data	10

Table 23 Extreme climate probability of non-exceedance distribution and Weibull parameters for El Farito station original data

Return period (years)	P restored data (mm)	P original data (mm)
1	9.3	2
5	32.85	38.91
10	38.77	45.13
25	45.64	51.89
50	50.36	56.31
75	52.97	58.69
100	54.77	60.30
150	57.24	62.48
250	50.24	65.08
300	61.29	65.98
400	62.92	67.37
500	64.16	68.41

Table 24 Precipitation for El Farito station given a return period

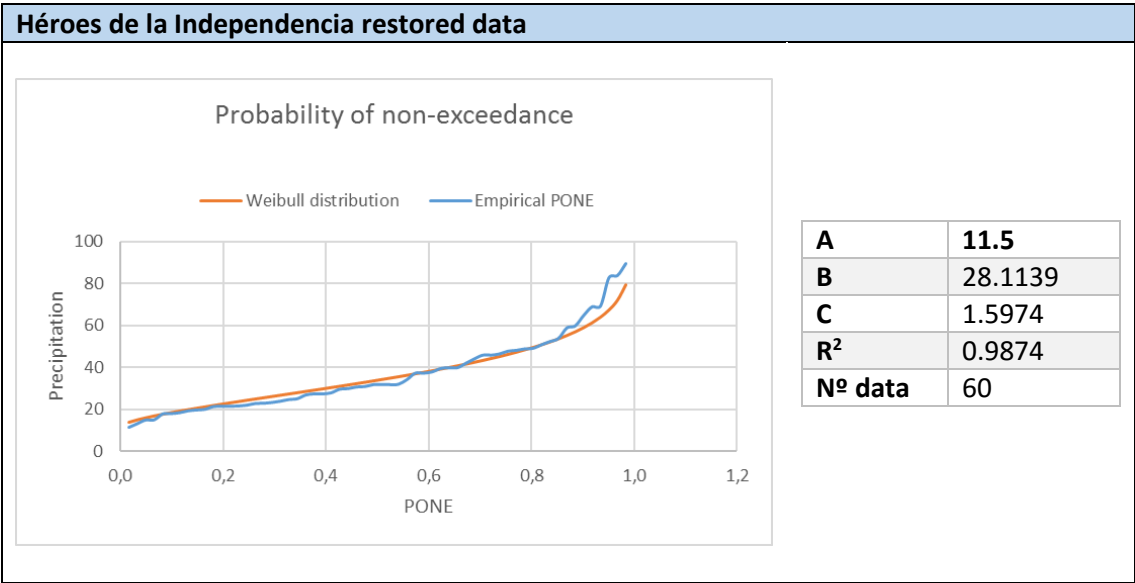


Table 25 Extreme climate probability of non-exceedance distribution and Weibull parameters for Héroes de la Independencia station restored data

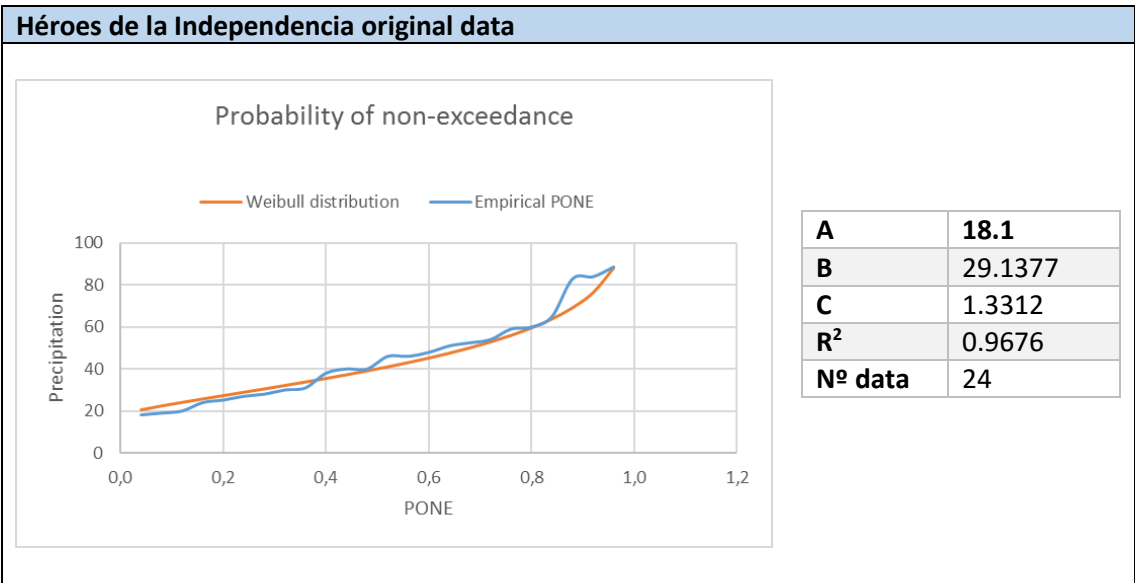


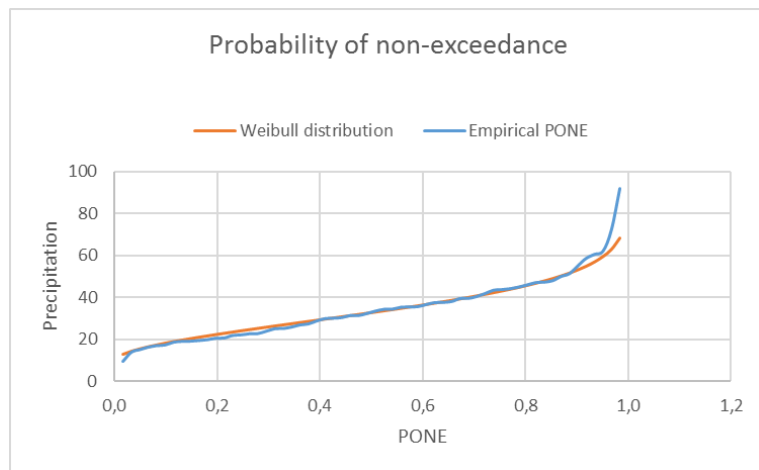
Table 26 Extreme climate probability of non-exceedance distribution and Weibull parameters for Héroes de la Independencia station original data

Return period (years)	P restored data (mm)	P original data (mm)
1	11.5	18.1
5	49.37	59.76
10	58.89	72.62
25	69.95	88.22
50	77.54	99.29
75	81.74	105.53
100	84.63	109.87
150	88.60	115.88
250	93.43	123.27
300	95.12	125.87
400	97.73	129.93
500	99.73	133.04

Table 27 Precipitation for Héroes de la Independencia station given a return period

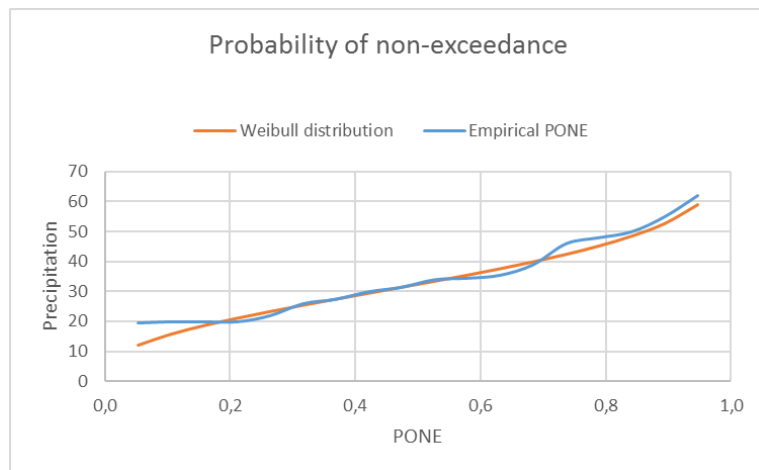
La Bocana

La Bocana restored data



A	9.7
B	28.0608
C	1.9169
R²	0.9758
Nº data	60

Table 28 Extreme climate probability of non-exceedance distribution and Weibull parameters for La Bocana station restored data

La Bocana original data

A	2
B	35.5313
C	2.3003
R²	0.9680
Nº data	18

Table 29 Extreme climate probability of non-exceedance distribution and Weibull parameters for La Bocana station original data

Return period (years)	P restored data (mm)	P original data (mm)
1	9.70	2
5	45.67	45.70
10	53.06	53.06
25	61.34	61.06
50	66.87	66.29
75	69.88	69.11
100	71.94	71.02
150	74.75	73.59
250	78.13	76.68
300	79.29	77.74
400	81.10	79.38
500	82.48	80.68

Table 30 Precipitation for La Bocana station given a return period

Maneadero

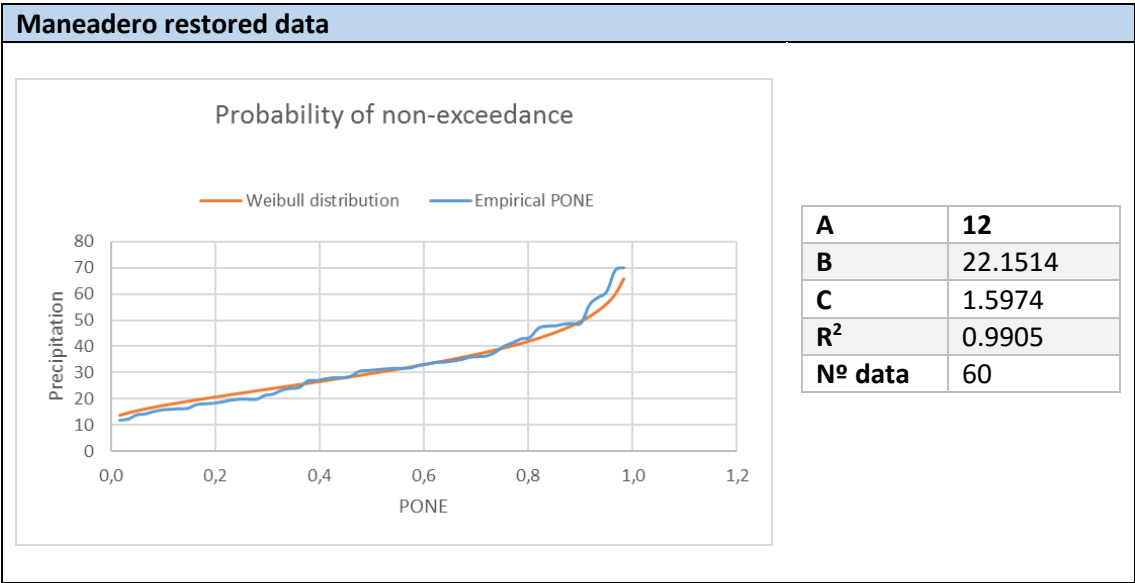


Table 31 Extreme climate probability of non-exceedance distribution and Weibull parameters for Maneadero station restored data

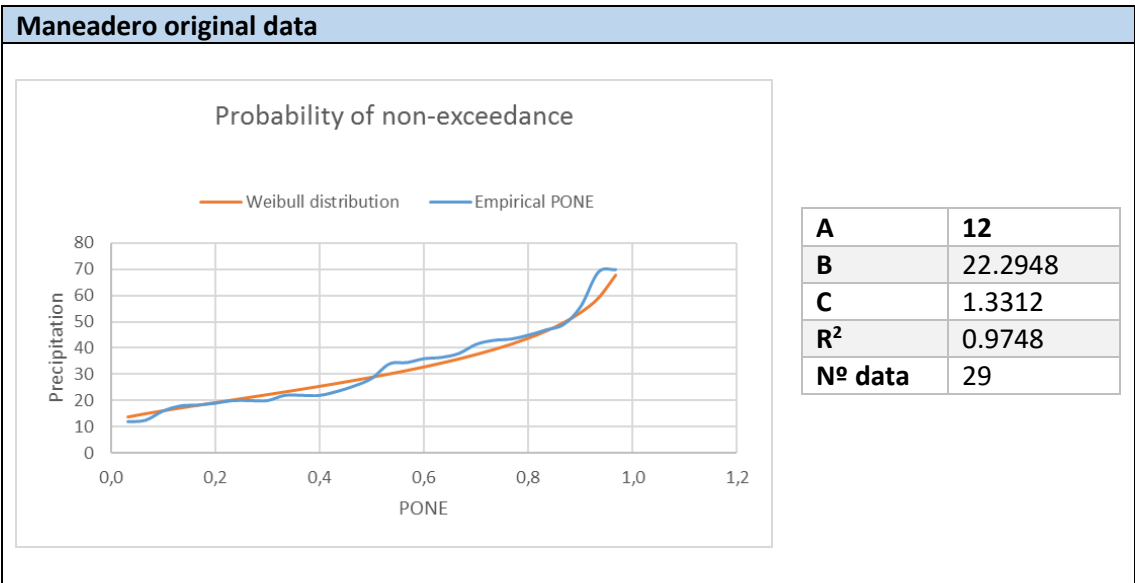


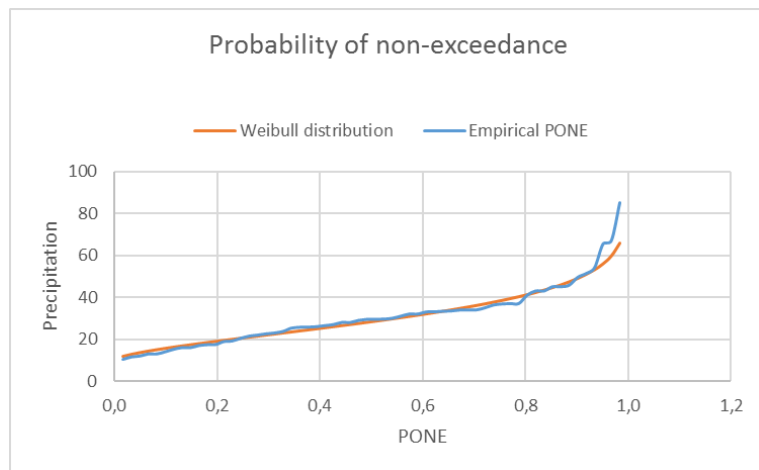
Table 32 Extreme climate probability of non-exceedance distribution and Weibull parameters for Maneadero station original data

Return period (years)	P restored data (mm)	P original data (mm)
1	12	12
5	41.84	43.88
10	49.34	53.72
25	58.05	65.65
50	64.03	74.12
75	67.34	78.90
100	69.62	82.22
150	72.75	86.81
250	76.56	92.47
300	77.88	94.46
400	79.94	97.57
500	81.52	99.95

Table 33 Precipitation for Maneadero station given a return period

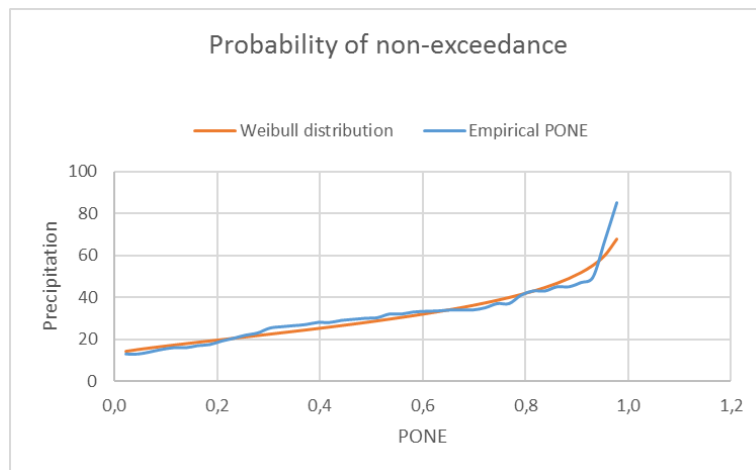
Ojos Negros

Ojos Negros restored data



A	10.4
B	22.8112
C	1.5974
R²	0.9738
Nº data	60

Table 34 Extreme climate probability of non-exceedance distribution and Weibull parameters for Ojos Negros station restored data

Ojos Negros original data


A	13
B	20.2060
C	1.3312
R²	0.9519
Nº data	42

Table 35 Extreme climate probability of non-exceedance distribution and Weibull parameters for Ojos Negros station original data

Return period (years)	P restored data (mm)	P original data (mm)
1	10.4	13
5	41.13	41.89
10	48.85	50.81
25	57.82	61.63
50	63.98	69.30
75	67.39	73.63
100	69.74	76.64
150	72.96	80.80
250	76.88	85.93
300	78.25	87.74
400	80.37	90.55
500	81.99	92.71

Table 36 Precipitation for Ojos Negros station given a return period

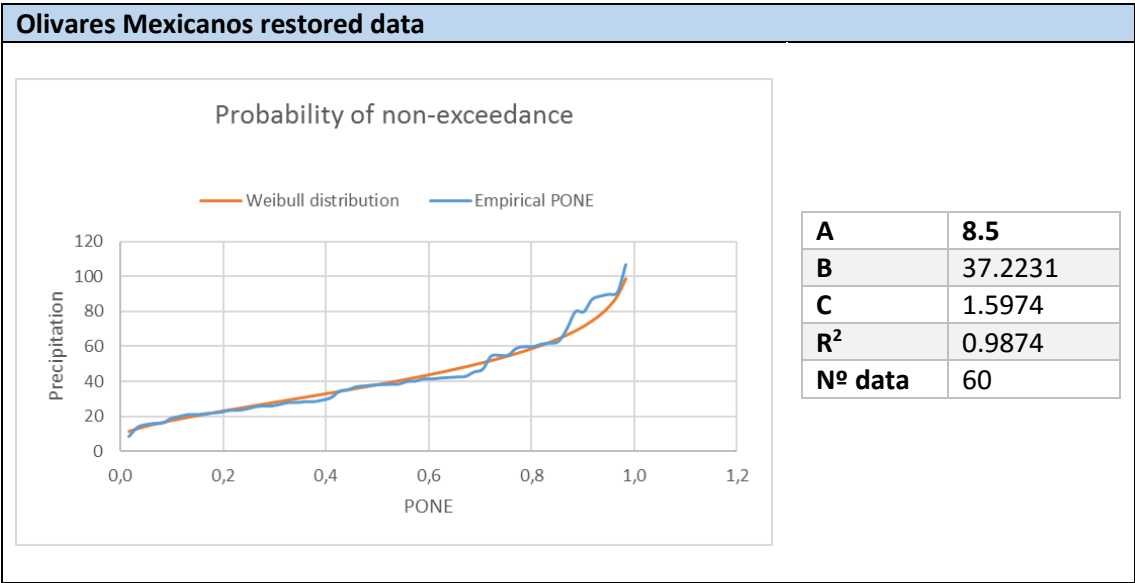


Table 37 Extreme climate probability of non-exceedance distribution and Weibull parameters for Olivares Mexicanos station restored data

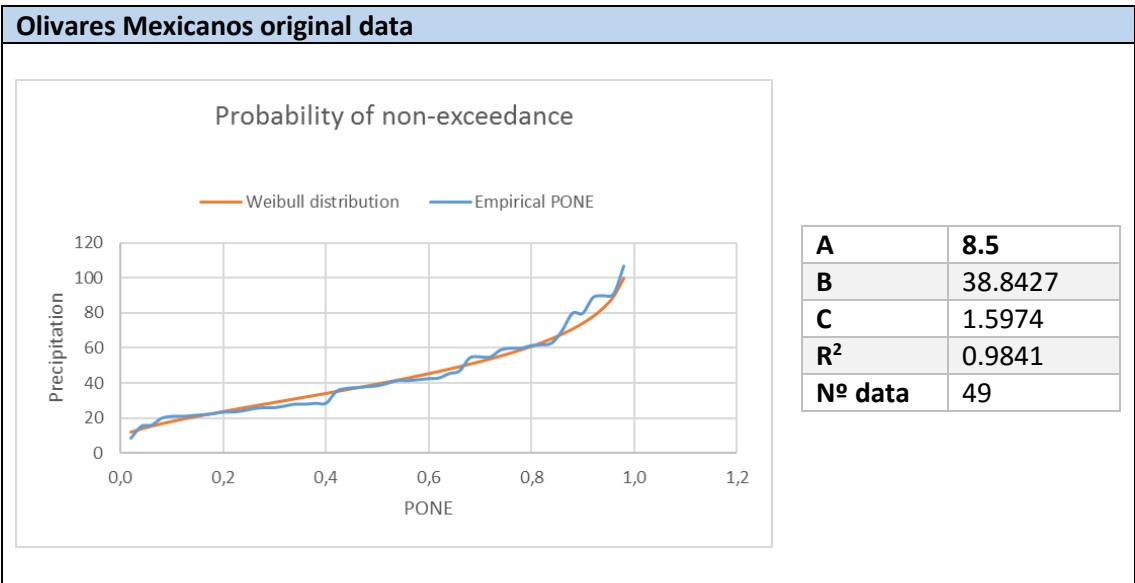


Table 38 Extreme climate probability of non-exceedance distribution and Weibull parameters for Olivares Mexicanos station original data

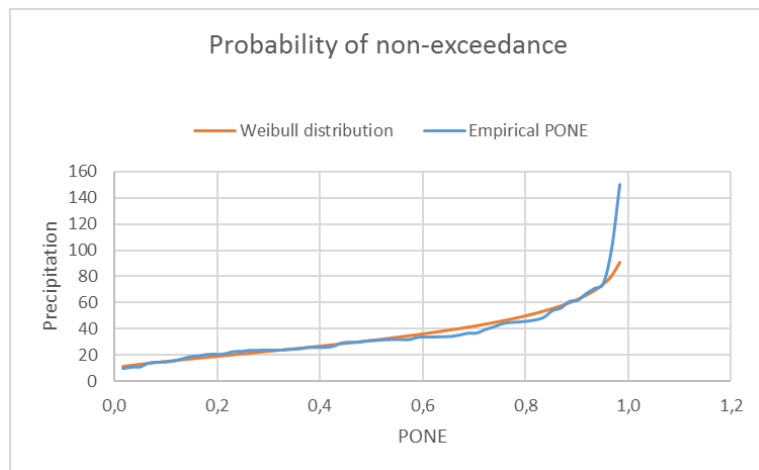
Rainfall Characterization of the Catchment Area of Ensenada, Baja California, México

Return period (years)	P restored data (mm)	P original data (mm)
1	8.5	8.5
5	58.64	60.82
10	71.24	73.97
25	85.88	89.25
50	95.93	99.74
75	101.5	105.55
100	105.33	109.54
150	110.58	115.03
250	116.98	121.70
300	119.21	124.03
400	122.67	127.64
500	125.32	130.40

Table 39 Precipitation for Olivares Mexicanos station given a return period

Punta Banda

Punta Banda restored data



A	10
B	27.9566
C	1.3312
R²	0.9077
Nº data	60

Table 40 Extreme climate probability of non-exceedance distribution and Weibull parameters for Punta Banda station restored data

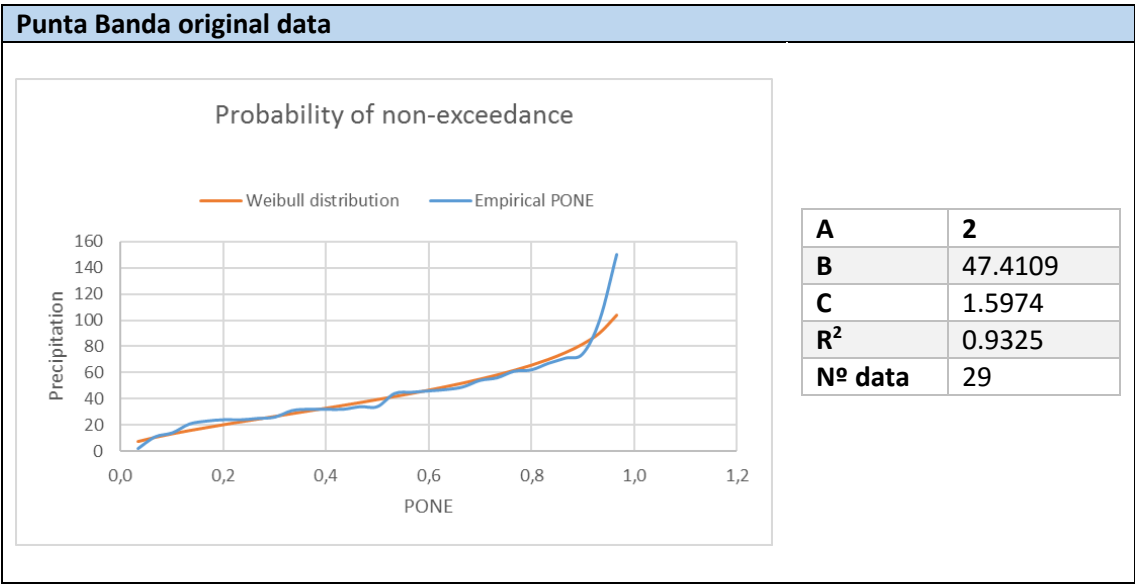


Table 41 Extreme climate probability of non-exceedance distribution and Weibull parameters for Punta Banda station original data

Return period (years)	P restored data (mm)	P original data (mm)
1	10	2
5	49.97	65.86
10	62.31	81.92
25	77.28	100.56
50	87.89	113.36
75	93.88	120.45
100	98.05	125.33
150	103.81	132.02
250	110.91	140.17
300	113.40	143.01
400	117.30	147.42
500	120.28	150.79

Table 42 Precipitation for Punta Banda station given a return period

Real del Castillo

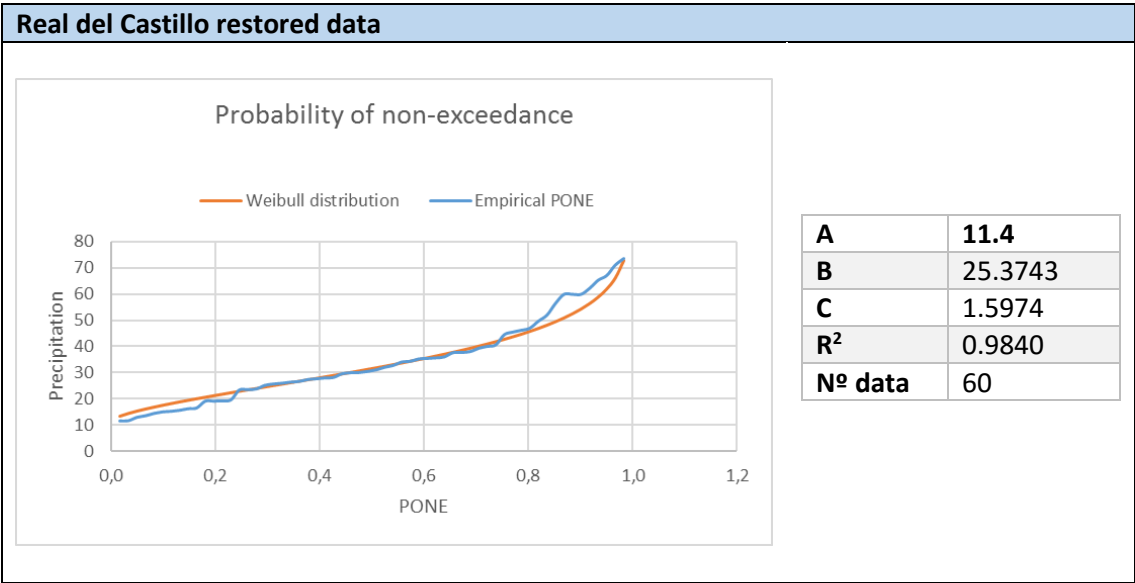


Table 43 Extreme climate probability of non-exceedance distribution and Weibull parameters for Real del Castillo station restored data

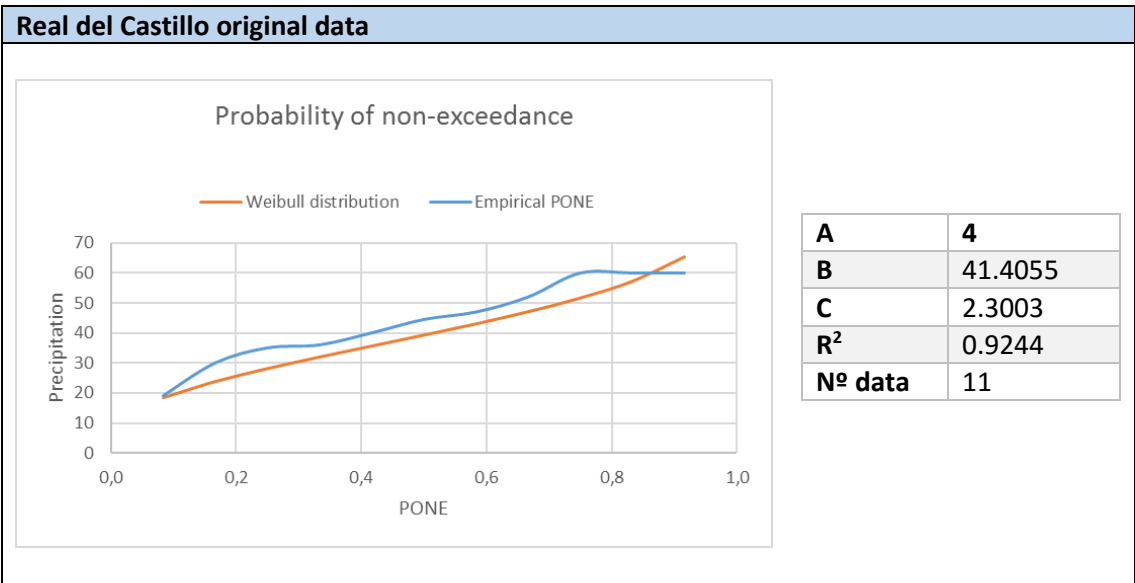


Table 44 Extreme climate probability of non-exceedance distribution and Weibull parameters for Real del Castillo station original data

Return period (years)	P restored data (mm)	P original data (mm)
1	11.4	4
5	45.58	54.92
10	54.17	63.50
25	64.15	72.83
50	71.00	78.92
75	74.80	82.20
100	77.41	84.43
150	80.99	87.43
250	85.35	91.03
300	86.87	92.26
400	89.23	94.17
500	91.03	95.62

Table 45 Precipitation for Real del Castillo station given a return period

San Carlos

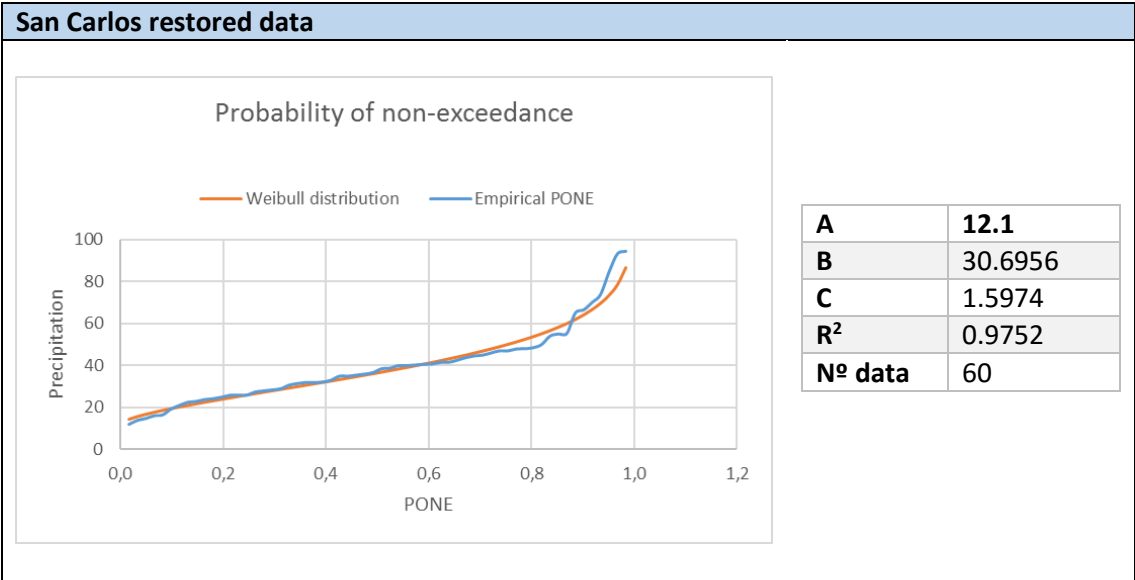
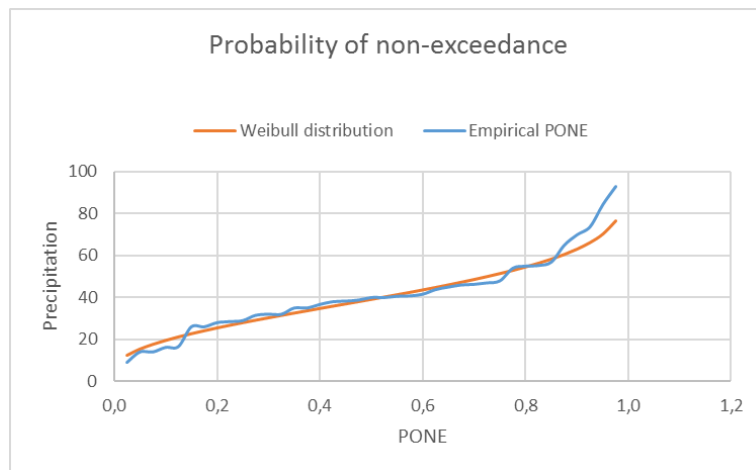


Table 46 Extreme climate probability of non-exceedance distribution and Weibull parameters for San Carlos station restored data

San Carlos original data



A	4
B	41.0758
C	2.3003
R²	0.9689
Nº data	39

Table 47 Extreme climate probability of non-exceedance distribution and Weibull parameters for San Carlos station original data

Return period (years)	P restored data (mm)	P original data (mm)
1	12.10	4
5	53.45	54.52
10	63.84	63.03
25	75.91	72.28
50	84.20	78.32
75	88.79	81.58
100	91.95	83.79
150	96.28	86.77
250	101.56	90.33
300	103.39	91.56
400	106.25	93.46
500	108.43	94.89

Table 48 Precipitation for San Carlos station given a return period

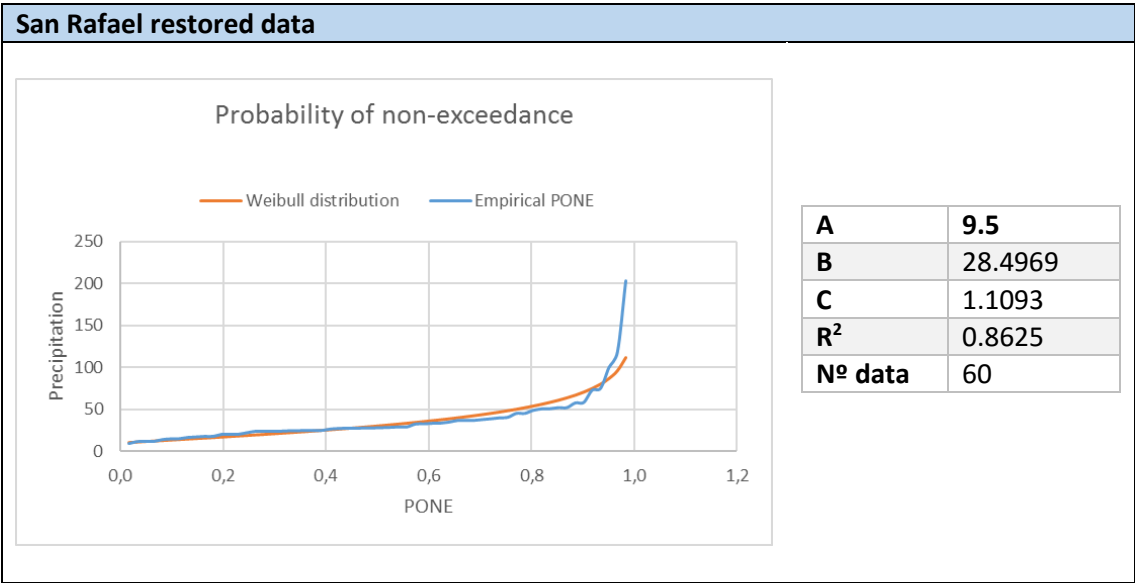


Table 49 Extreme climate probability of non-exceedance distribution and Weibull parameters for San Rafael station restored data

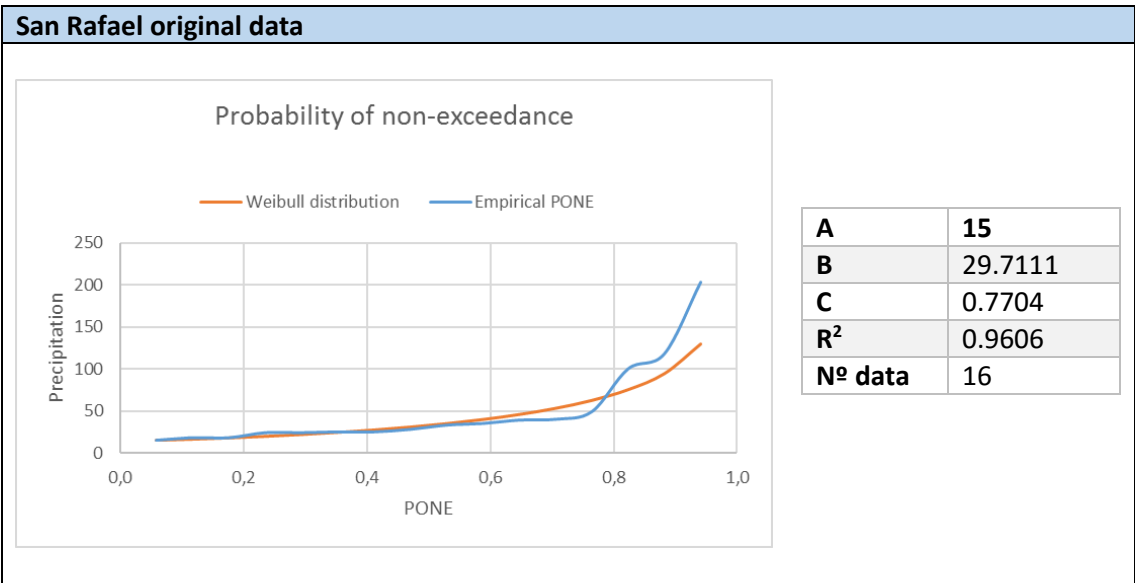


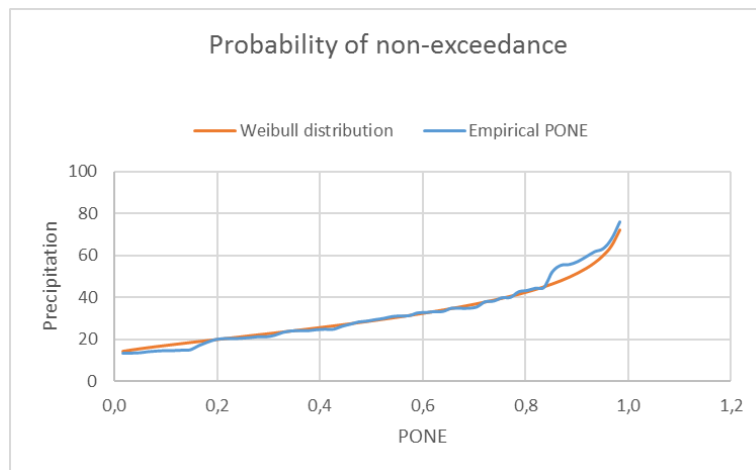
Table 50 Extreme climate probability of non-exceedance distribution and Weibull parameters for San Rafael station original data

Return period (years)	P restored data (mm)	P original data (mm)
1	9.5	15
5	53.26	70.11
10	69.94	102.72
25	91.25	150.51
50	106.96	189.55
75	116.02	213.39
100	122.40	230.72
150	131.32	255.69
250	142.46	288.01
300	146.42	299.77
400	152.63	318.56
500	157.42	333.31

Table 51 Precipitation for San Rafael station given a return period

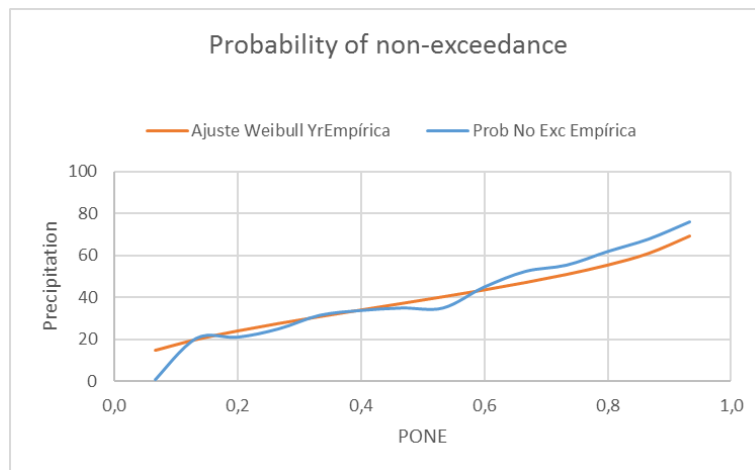
Santa Isabel

Santa Isabel restored data



A	13.5
B	20.2265
C	1.3312
R²	0.9879
Nº data	60

Table 52 Extreme climate probability of non-exceedance distribution and Weibull parameters for Santa Isabel station restored data

Santa Isabel original data

A	0.7
B	44.4979
C	2.3003
R²	0.9719
Nº data	14

Table 53 Extreme climate probability of non-exceedance distribution and Weibull parameters for Santa Isabel station original data

Return period (years)	P restored data (mm)	P original data (mm)
1	13.50	0.70
5	42.42	55.43
10	51.35	64.65
25	62.18	74.67
50	69.86	81.22
75	74.19	84.74
100	77.20	87.13
150	81.37	90.36
250	86.51	94.23
300	88.31	95.56
400	91.13	97.61
500	93.29	99.16

Table 54 Precipitation for Santa Isabel station given a return period

Santo Tomás

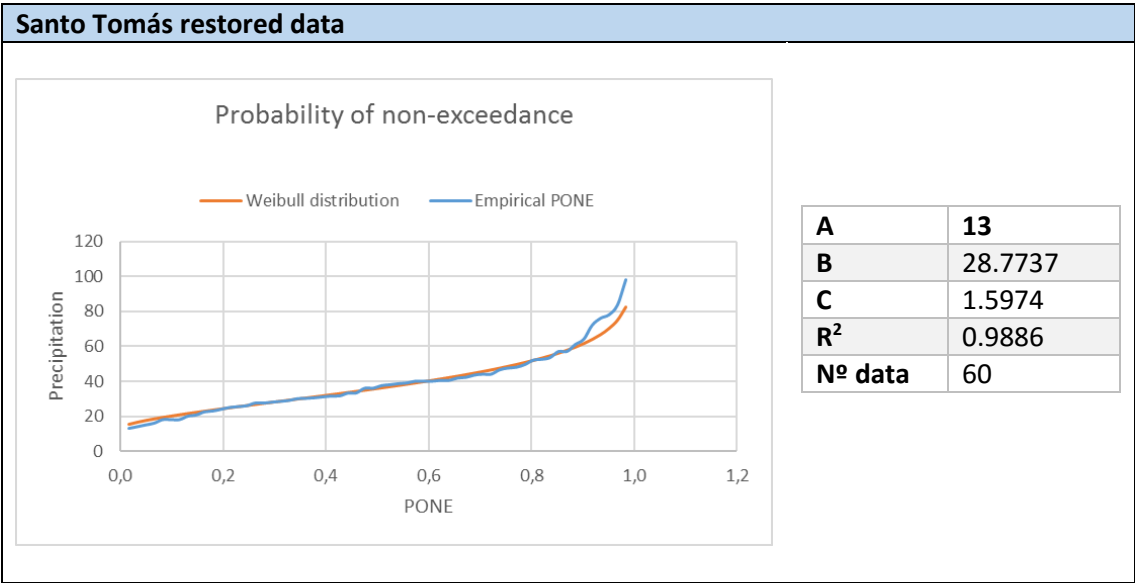


Table 55 Extreme climate probability of non-exceedance distribution and Weibull parameters for Santo Tomás station restored data

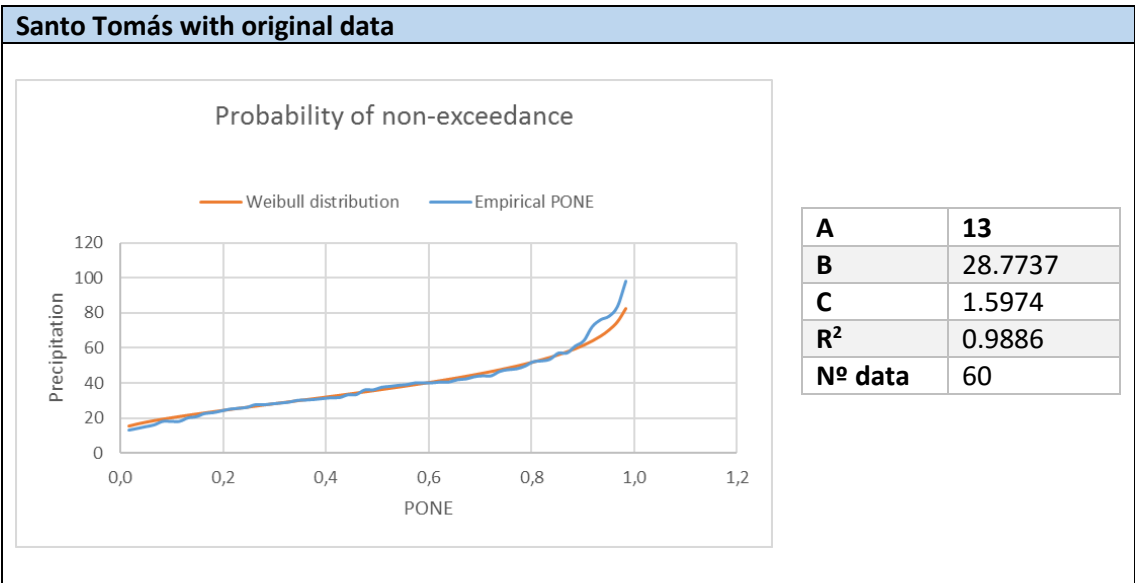


Table 56 Extreme climate probability of non-exceedance distribution and Weibull parameters for Santo Tomás station original data

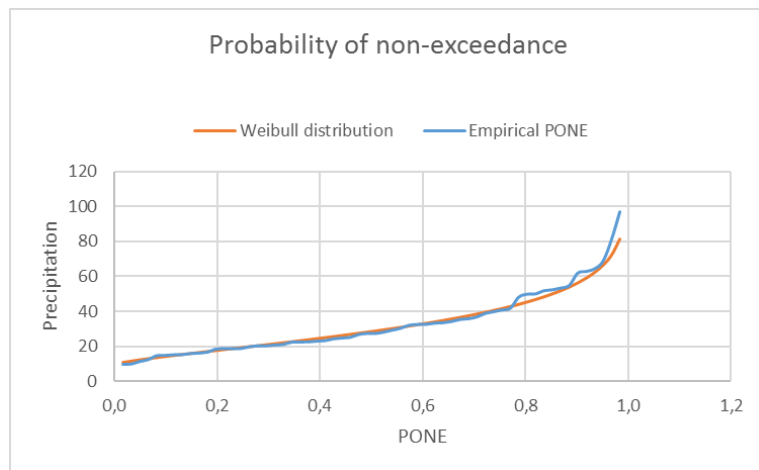
This meteorological station has the particularity of having the most number of original data. As can be seen, the adjusted parameters are identical.

Return period (years)	P restored data (mm)	P original data (mm)
1	13	13
5	51.76	51.76
10	61.50	61.50
25	72.82	72.82
50	80.58	80.58
75	84.89	84.89
100	87.85	87.85
150	91.91	91.91
250	96.86	96.86
300	98.58	98.58
400	101.26	101.26
500	103.30	103.30

Table 57 Precipitation for Santo Tomás station given a return period

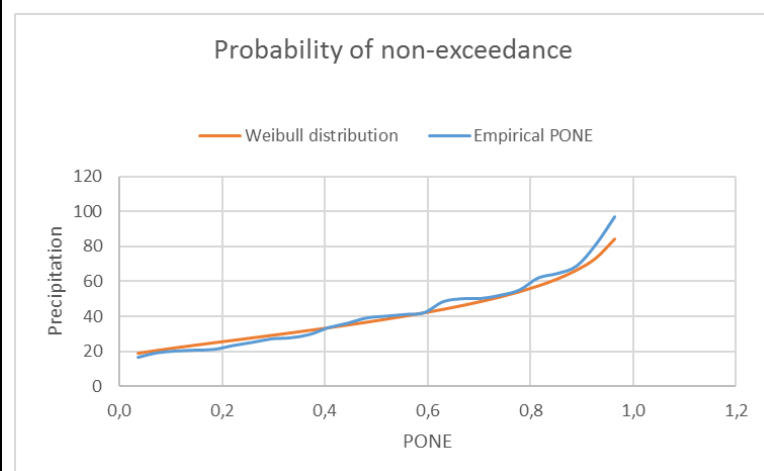
Sierra de Juárez

Sierra de Juárez restored data



A	9.9
B	24.7949
C	1.3312
R²	0.9927
Nº data	60

Table 58 Extreme climate probability of non-exceedance distribution and Weibull parameters for Sierra de Juárez station restored data

Sierra de Juárez original data

A	16.4
B	27.7415
C	1.3312
R²	0.9939
Nº data	26

Table 59 Extreme climate probability of non-exceedance distribution and Weibull parameters for Sierra de Juárez station original data

Return period (years)	P restored data (mm)	P original data (mm)
1	9.90	16.40
5	45.35	56.06
10	56.29	68.31
25	69.57	83.16
50	78.99	93.70
75	84.30	99.64
100	87.99	103.77
150	93.10	109.49
250	99.40	116.53
300	101.61	119.01
400	105.06	122.87
500	107.71	125.84

Table 60 Precipitation for Sierra de Juárez station given a return period

The precipitation distributions for each meteorological station adjust extremely well to the Weibull distribution. As can be seen from the results, the A, B and C parameters are similar and the precipitation given a return period, have a maximum difference of about 15%.

Mean climate

The following charts and graphs present the Weibull parameters calculated for each station.

Also tables depict the expected rainfall given a certain probability of non-exceedance for each meteorological station, taking into account the restored and the original data.

A dash (-) that appears in the tables of precipitation given a probability of non-exceedance when all the data is considered means a negative value of expected precipitation found by the interpolation method and has no physical significance.

Considering all the data

This part considers all the data available, including the 0mm precipitation values.

Tables 61 to 111 show the probability of non-exceedance distribution and Weibull parameters for each station considering restored and original data; also, the comparison between the precipitation values for a given probability of non-exceedance, where the values marked under *W* were obtained using the Weibull distribution formula and those marked under *I* were obtained using linear interpolation between the data and the empirical PONE.

Presa ELZ

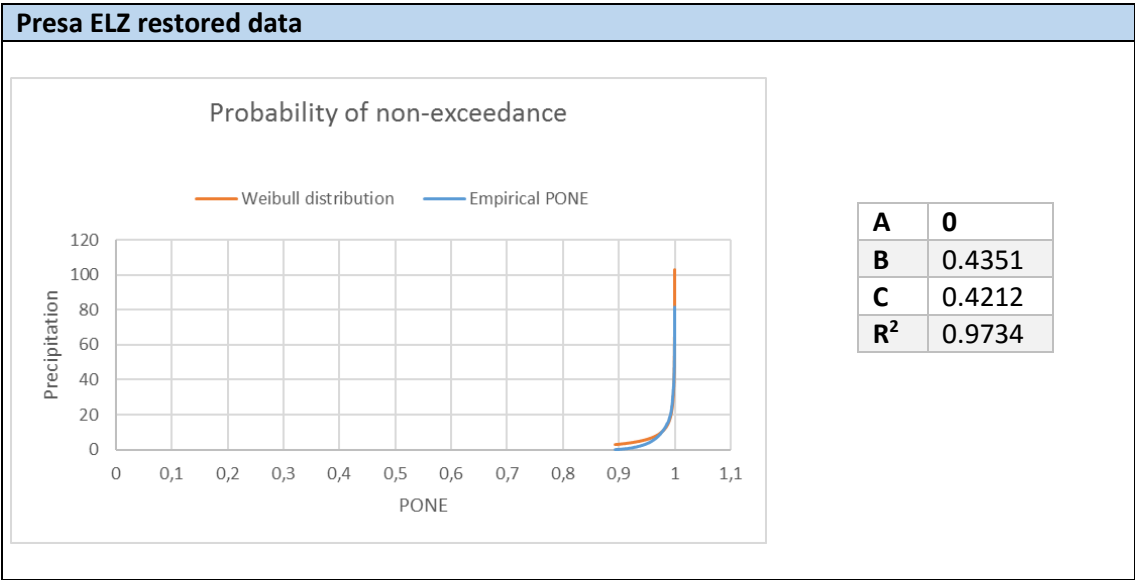
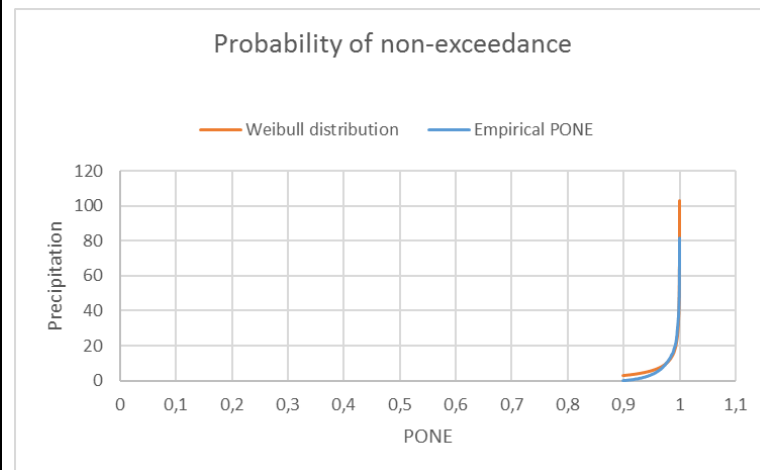


Table 61 Mean climate, considering all data, probability of non-exceedance distribution and Weibull parameters for Presa ELZ station restored data

Presa ELZ original data



A	0
B	0.4322
C	0.4183
R²	0.9716

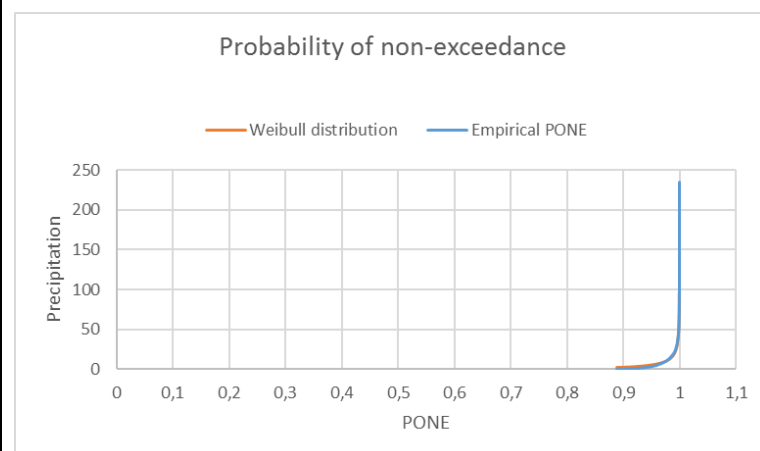
Table 62 Mean climate, considering all data, probability of non-exceedance distribution and Weibull parameters for Presa ELZ station original data

Variable	Precipitation for probability of non-exceedance (mm)											
	0.5		0.75		0.8		0.9		0.99		0.999	
	W	I	W	I	W	I	W	I	W	I	W	I
Restored data	0.18	-	0.94	-	1.35	-	3.15	0.42	16.34	17.4	42.78	43.62
Original data	0.18	-	0.94	-	1.35	-	3.17	0.05	23.27	18.05	43.87	44.85

Table 63 Precipitation values given a probability of non-exceedance for Presa ELZ station, mean climate, considering all data

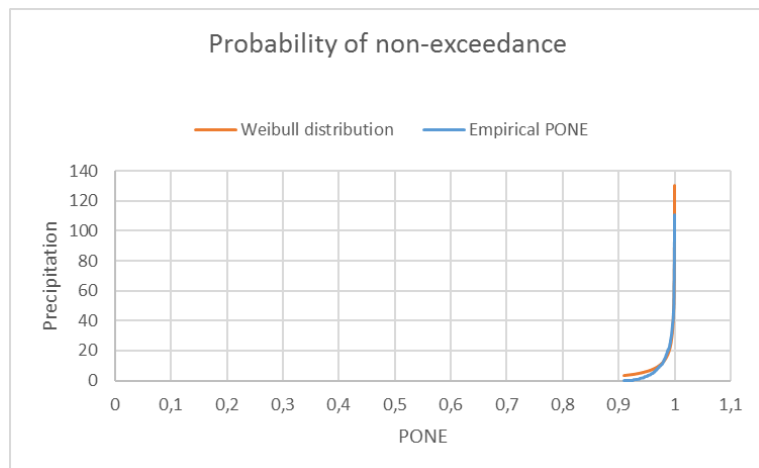
Ejido Uruapan

Ejido Uruapan restored data



A	0
B	0.2411
C	0.3508
R²	0.9605

Table 64 Mean climate, considering all data, probability of non-exceedance distribution and Weibull parameters for Ejido Uruapan station restored data

Ejido Uruapan original data

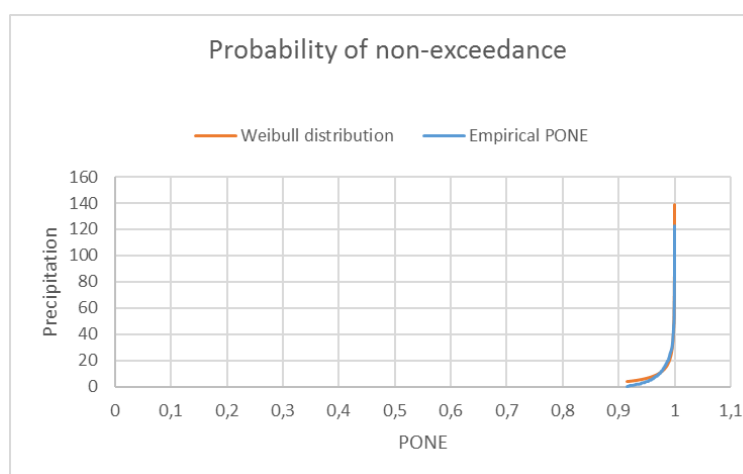
A	0
B	0.2912
C	0.3620
R²	0.9806

Table 65 Mean climate, considering all data, probability of non-exceedance distribution and Weibull parameters for Ejido Uruapan station original data

Variable	Precipitation for probability of non-exceedance (mm)											
	0.5		0.75		0.8		0.9		0.99		0.999	
	W	I	W	I	W	I	W	I	W	I	W	I
Restored data	0.08	-	0.61	-	0.94	-	2.6	0.25	18.73	20.31	59.5	55.11
Original data	0.11	-	0.72	-	1.08	-	2.92	-	19.78	21.85	60.61	65.01

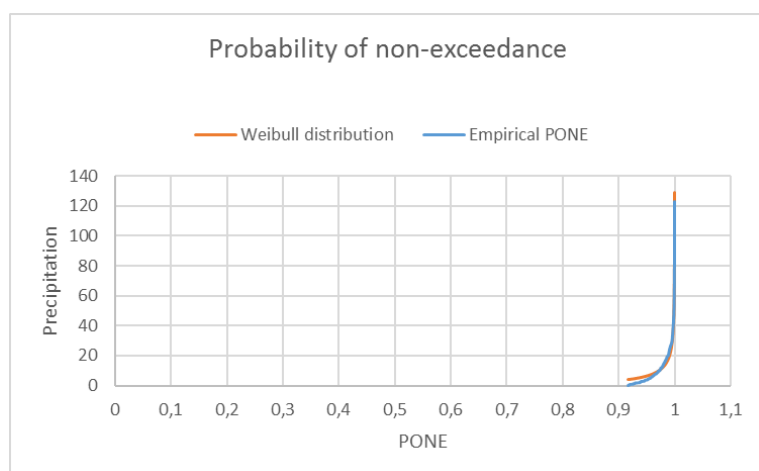
Table 66 Precipitation values given a probability of non-exceedance for Ejido Uruapan station, mean climate, considering all data

El Álamo

El Álamo with restored data

A	0
B	0.3984
C	0.3933
R²	0.9858

Table 67 Mean climate, considering all data, probability of non-exceedance distribution and Weibull parameters for El Álamo station restored data

El Álamo with original data

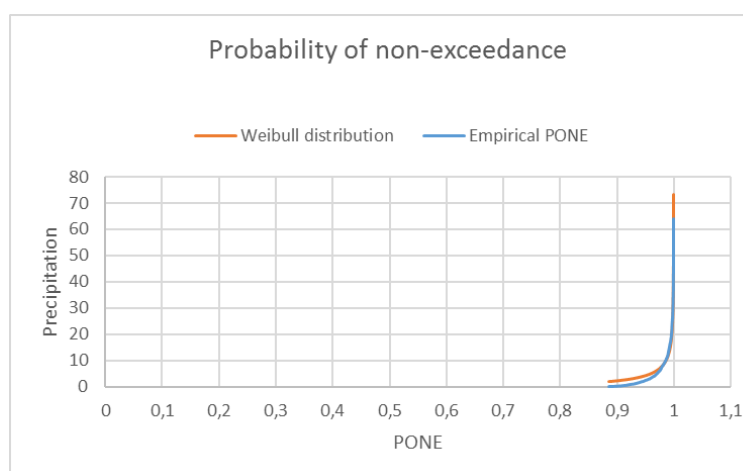
A	0
B	0.3674
C	0.3874
R²	0.9853

Table 68 Mean climate, considering all data, probability of non-exceedance distribution and Weibull parameters for El Álamo station original data

Variable	Precipitation for probability of non-exceedance (mm)											
	0.5		0.75		0.8		0.9		0.99		0.999	
	W	I	W	I	W	I	W	I	W	I	W	I
Restored data	0.16	-	0.91	-	1.34	-	3.32	-	19.36	21.99	54.28	52.06
Original data	0.14	-	0.85	-	1.26	-	3.16	-	18.94	22.6	53.95	52.52

Table 69 Precipitation values given a probability of non-exceedance for El Álamo station, mean climate, considering all data

El Ciprés

El Ciprés restored data

A	0
B	0.3171
C	0.4228
R²	0.9754

Table 70 Mean climate, considering all data, probability of non-exceedance distribution and Weibull parameters for El Ciprés station restored data

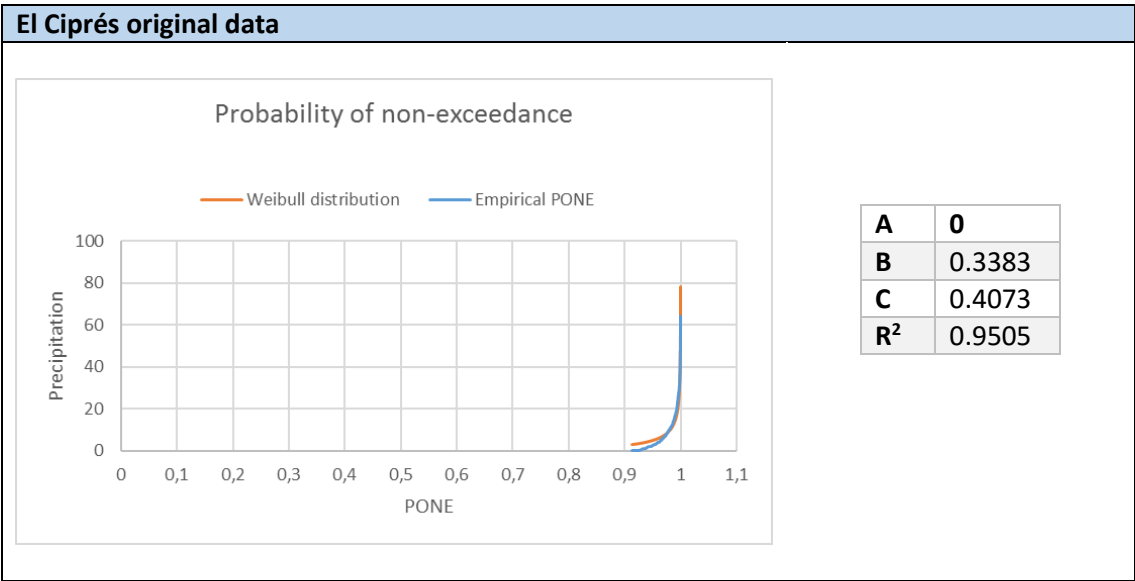


Table 71 Mean climate, considering all data, probability of non-exceedance distribution and Weibull parameters for El Ciprés station original data

Variable	Precipitation for probability of non-exceedance (mm)											
	0.5		0.75		0.8		0.9		0.99		0.999	
	W	I	W	I	W	I	W	I	W	I	W	I
Restored data	0.13	-	0.69	-	0.98	-	2.28	0.19	11.75	12.09	30.65	31.41
Original data	0.14	-	0.75	-	1.09	-	2.62	-	14.38	16.68	38.91	37.32

Table 72 Precipitation values given a probability of non-exceedance for El Ciprés station, mean climate, considering all data

El Farito

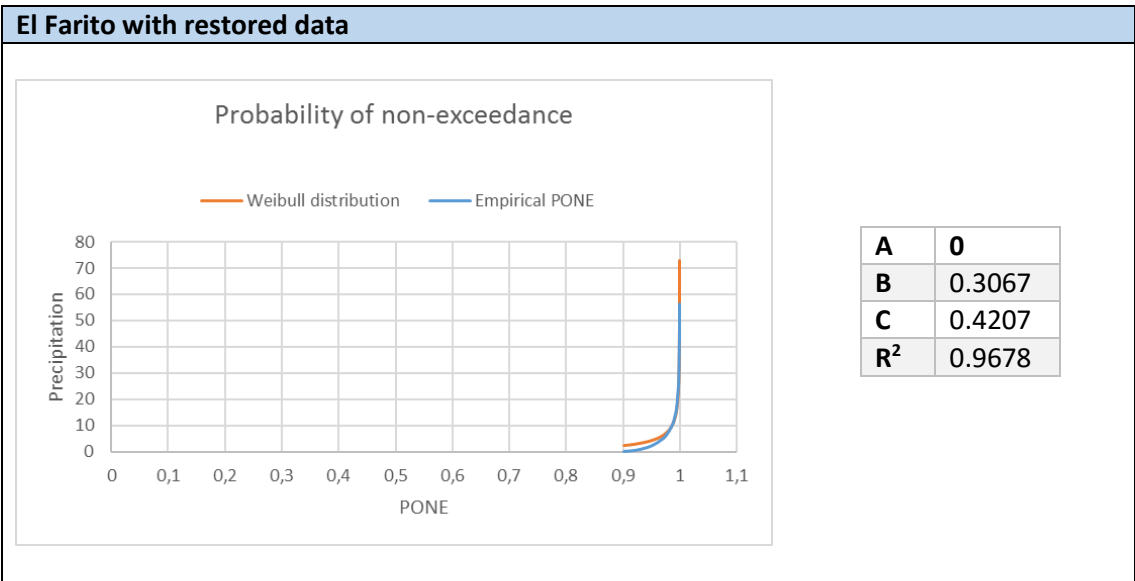


Table 73 Mean climate, considering all data, probability of non-exceedance distribution and Weibull parameters for El Farito station restored data

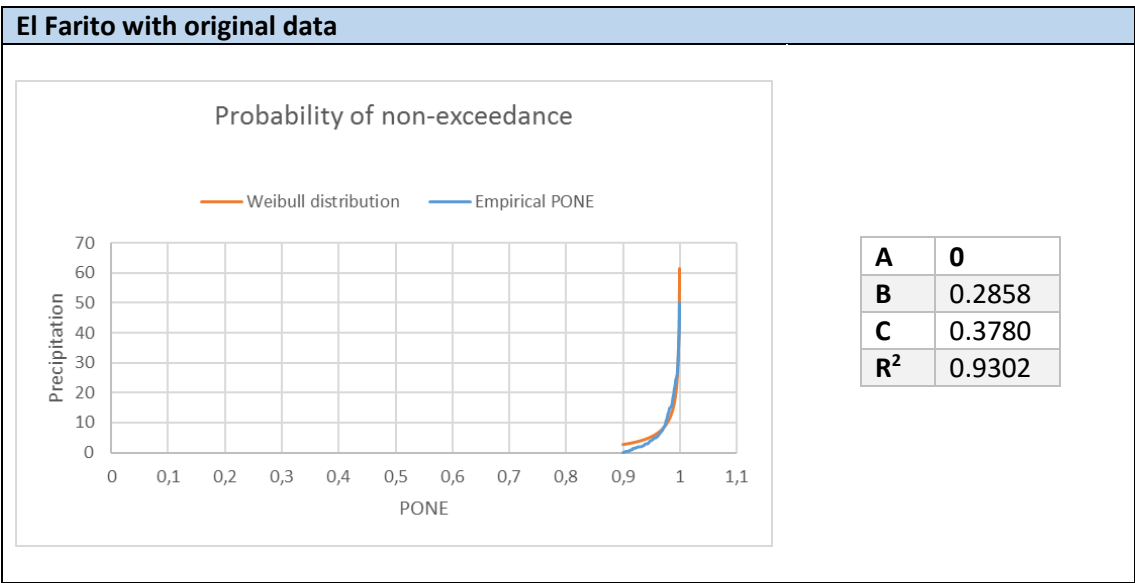


Table 74 Mean climate, considering all data, probability of non-exceedance distribution and Weibull parameters for El Farito station original data

Variable	Precipitation for probability of non-exceedance (mm)											
	0.5		0.75		0.8		0.9		0.99		0.999	
	W	I	W	I	W	I	W	I	W	I	W	I
Restored data	0.13	-	0.67	-	0.95	-	2.23	-	11.57	11.88	30.32	31.66
Original data	0.11	-	0.68	-	1.01	-	2.60	-	16.25	20.88	47.50	40.48

Table 75 Precipitation values given a probability of non-exceedance for El Farito station, mean climate, considering all data

Héroes de la Independencia

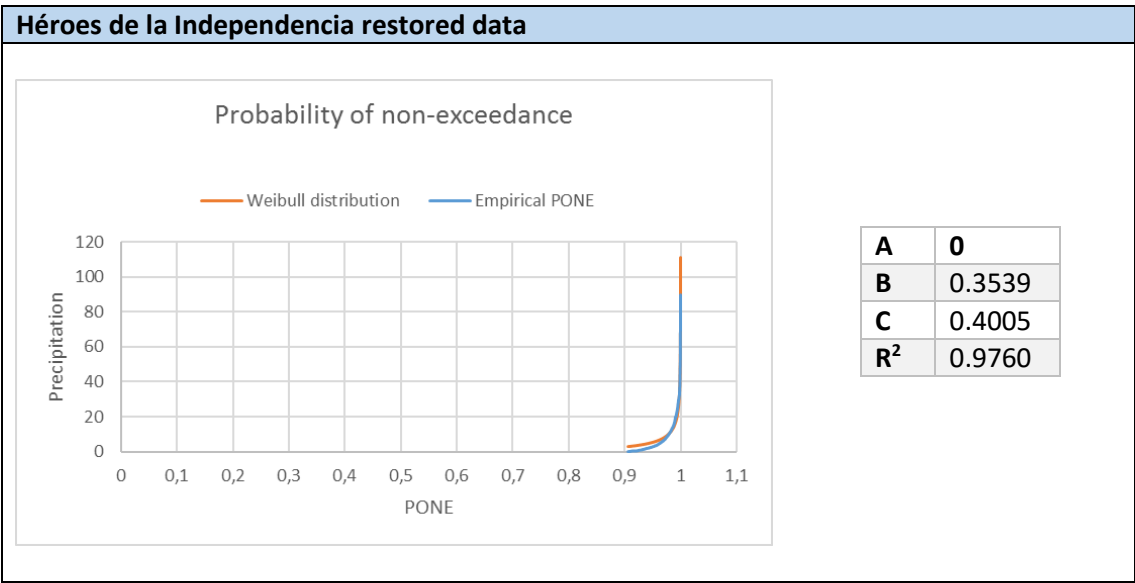


Table 76 Mean climate, considering all data, probability of non-exceedance distribution and Weibull parameters for Héroes de la Independencia station restored data

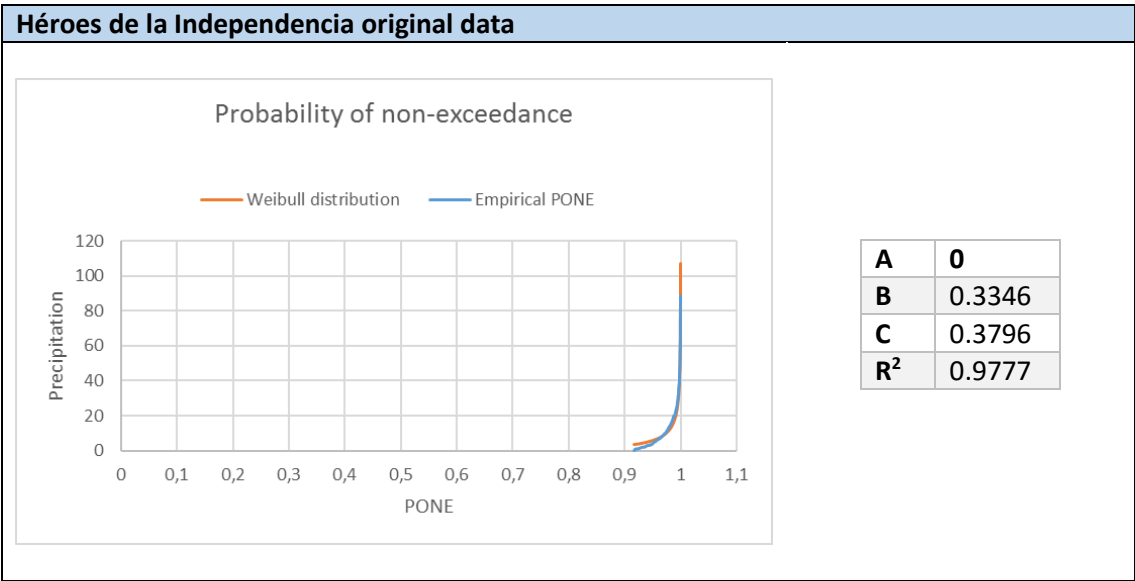


Table 77 Mean climate, considering all data, probability of non-exceedance distribution and Weibull parameters for Héroes de la Independencia station original data

Variable	Precipitation for probability of non-exceedance (mm)											
	0.5		0.75		0.8		0.9		0.99		0.999	
	W	I	W	I	W	I	W	I	W	I	W	I
Restored data	0.14	-	0.8	-	1.16	-	2.84	-	16.03	18.23	44.12	44.32
Original data	0.13	-	0.79	-	1.17	-	3.01	-	18.69	20.49	54.39	53.09

Table 78 Precipitation values given a probability of non-exceedance for Héroes de la Independencia station, mean climate, considering all data

La Bocana

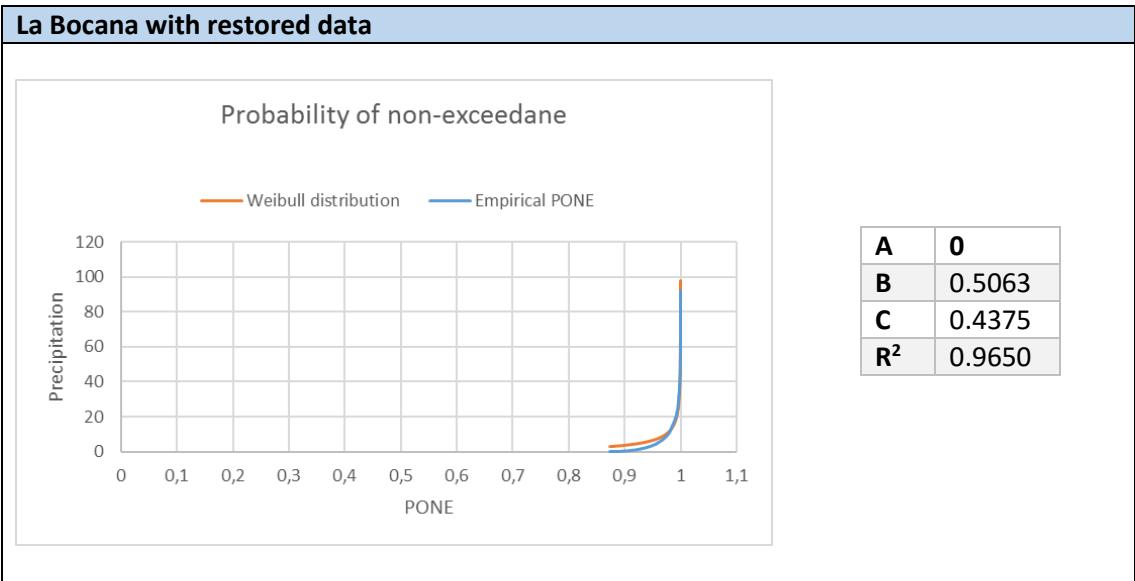
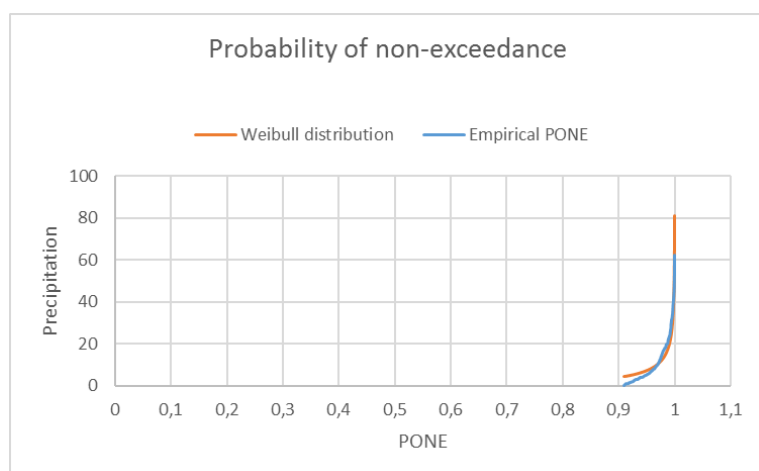


Table 79 Mean climate, considering all data, probability of non-exceedance distribution and Weibull parameters for La Bocana station restored data

La Bocana with original data



A	0
B	0.5574
C	0.4311
R²	0.9327

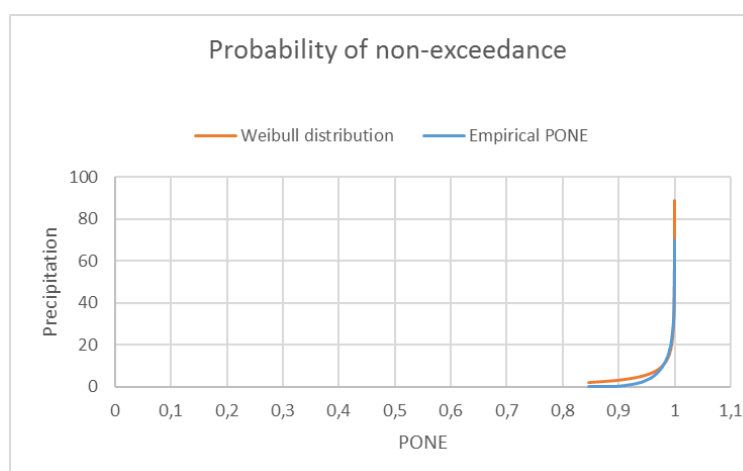
Table 80 Mean climate, considering all data, probability of non-exceedance distribution and Weibull parameters for La Bocana station original data

Variable	Precipitation for probability of non-exceedance (mm)											
	0.5		0.75		0.8		0.9		0.99		0.999	
	W	I	W	I	W	I	W	I	W	I	W	I
Restored data	0.22	-	1.07	-	1.5	-	3.41	0.35	16.61	18.12	41.96	42.96
Original data	0.24	-	1.19	-	1.68	-	3.86	-	19.27	22.94	49.35	45.78

Table 81 Precipitation values given a probability of non-exceedance for La Bocana station, mean climate, considering all data

Maneadero

Maneadero restored data



A	0
B	0.4535
C	0.4362
R²	0.9721

Table 82 Mean climate, considering all data, probability of non-exceedance distribution and Weibull parameters for Maneadero station restored data

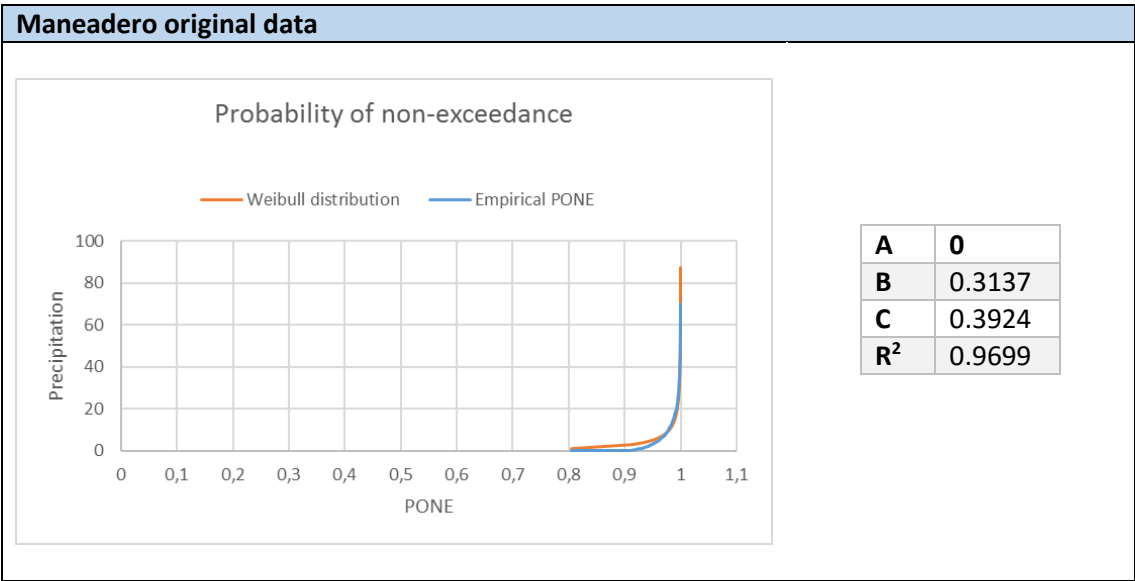


Table 83 Mean climate, considering all data, probability of non-exceedance distribution and Weibull parameters for Maneadero station original data

Variable	Precipitation for probability of non-exceedance (mm)											
	0.5		0.75		0.8		0.9		0.99		0.999	
	W	I	W	I	W	I	W	I	W	I	W	I
Restored data	0.2	-	0.96	-	1.35	-	3.07	0.21	15.04	16.44	38.09	37.65
Original data	0.12	-	0.72	-	1.05	0	2.63	0.09	15.37	17.89	43.18	43.53

Table 84 Precipitation values given a probability of non-exceedance for Maneadero station, mean climate, considering all data

Ojos Negros

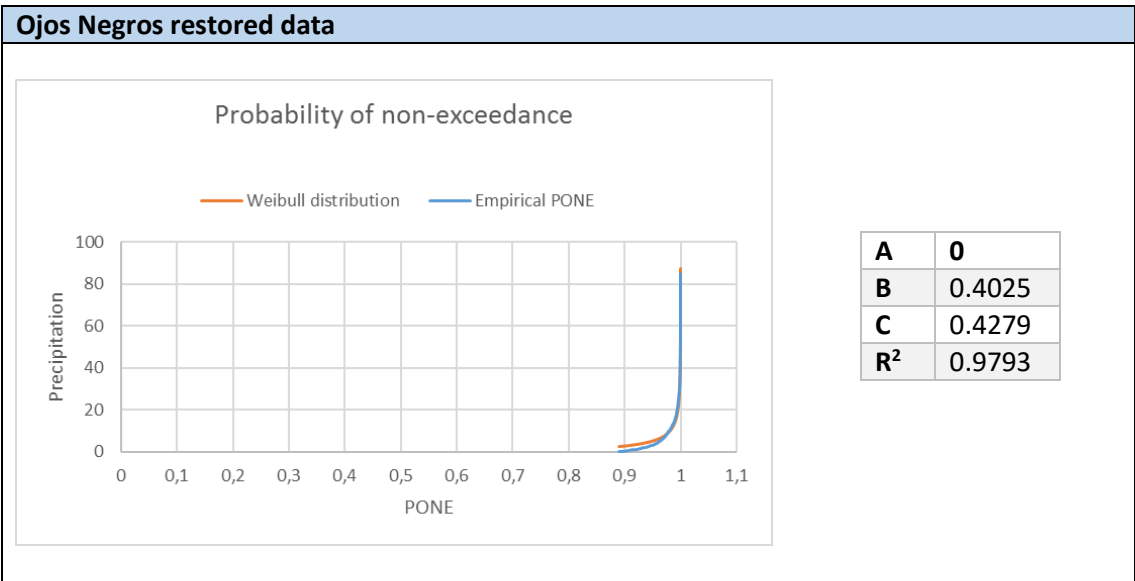
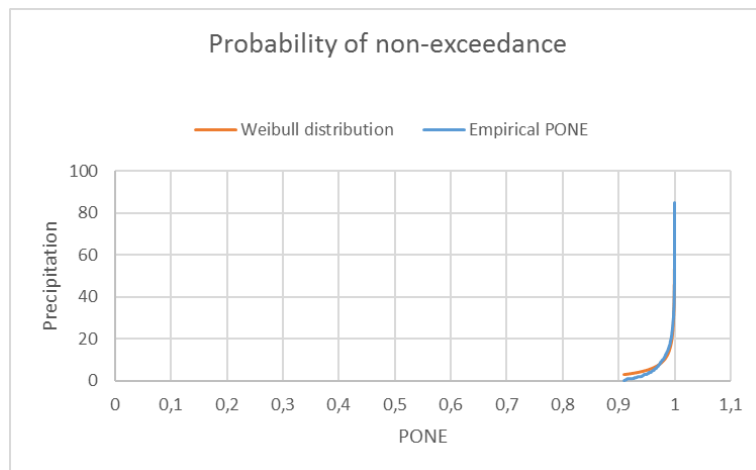


Table 85 Mean climate, considering all data, probability of non-exceedance distribution and Weibull parameters for Ojos Negros station restored data

Ojos Negros original data



A	0
B	0.3655
C	0.4178
R²	0.9701

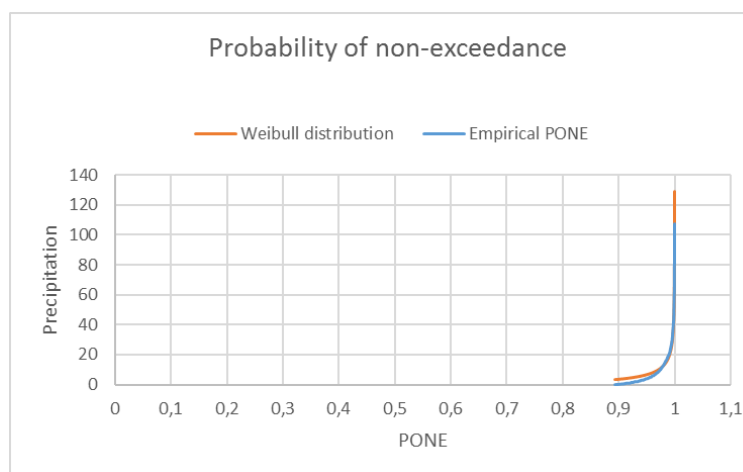
Table 86 Mean climate, considering all data, probability of non-exceedance distribution and Weibull parameters for Ojos Negros station original data

Variable	Precipitation for probability of non-exceedance (mm)											
	0.5		0.75		0.8		0.9		0.99		0.999	
	W	I	W	I	W	I	W	I	W	I	W	I
Restored data	0.17	-	0.86	-	1.22	-	2.83	0.27	14.28	15.54	36.82	36.87
Original data	0.15	-	0.80	-	1.14	-	2.69	-	14.13	16.23	37.30	36.66

Table 87 Precipitation values given a probability of non-exceedance for Maneadero station, mean climate, considering all data

Olivares Mexicanos

Olivares Mexicanos restored data



A	0
B	0.4130
C	0.4009
R²	0.9796

Table 88 Mean climate, considering all data, probability of non-exceedance distribution and Weibull parameters for Olivares Mexicanos station restored data

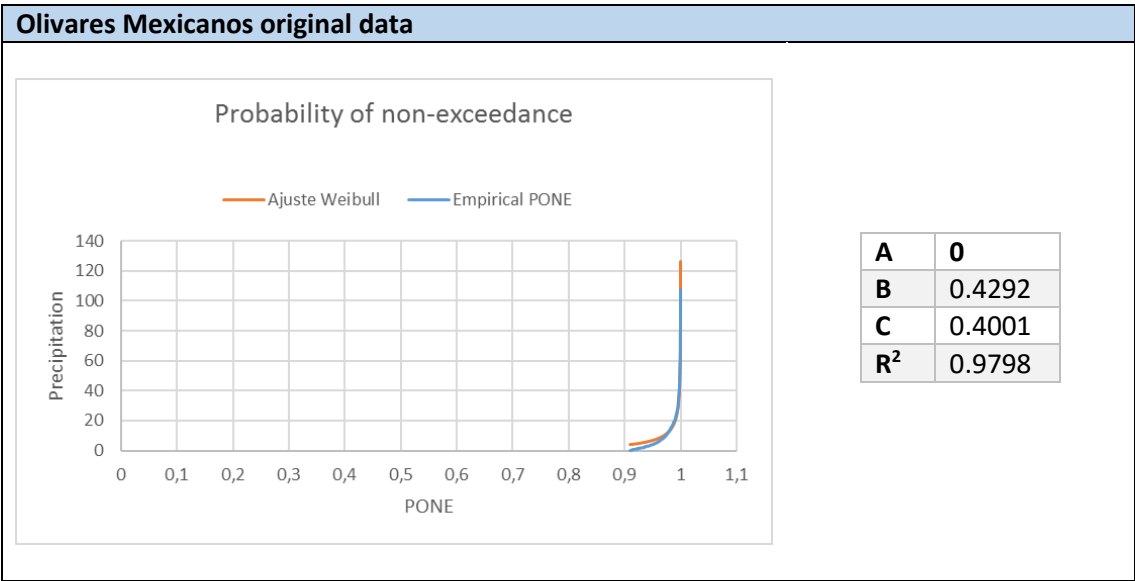


Table 89 Mean climate, considering all data, probability of non-exceedance distribution and Weibull parameters for Olivares Mexicanos station original data

Variable	Precipitation for probability of non-exceedance (mm)											
	0.5		0.75		0.8		0.9		0.99		0.999	
	W	I	W	I	W	I	W	I	W	I	W	I
Restored data	0.17	-	0.93	-	1.35	-	3.31	0.21	18.65	19.9	51.27	54.53
Original data	0.17	-	0.97	-	1.41	-	3.45	-	19.51	20.76	53.76	56.42

Table 90 Precipitation values given a probability of non-exceedance for Olivares Mexicanos station, mean climate, considering all data

Punta Banda

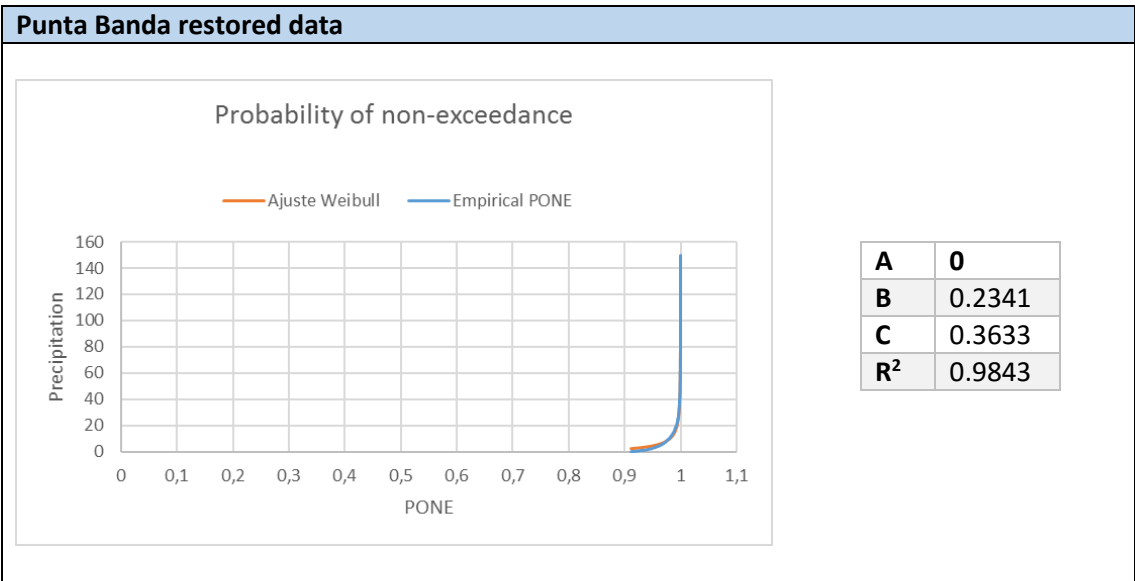
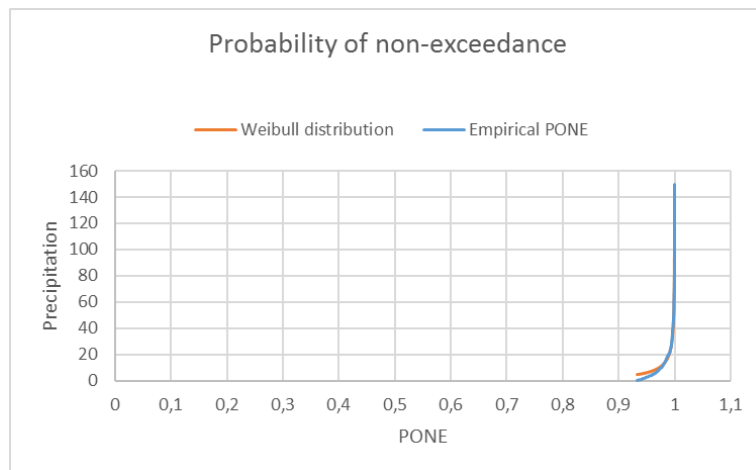


Table 91 Mean climate, considering all data, probability of non-exceedance distribution and Weibull parameters for Punta Banda station restored data

Punta Banda original data


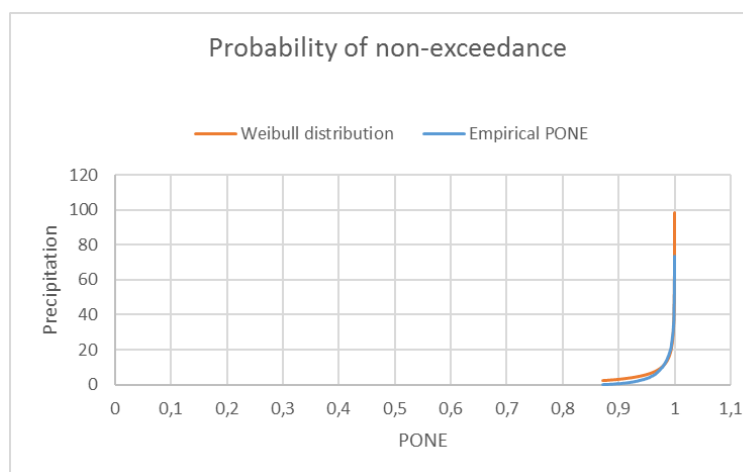
A	0
B	0.2624
C	0.3538
R²	0.9811

Table 92 Mean climate, considering all data, probability of non-exceedance distribution and Weibull parameters for Punta Banda station original data

Variable	Precipitation for probability of non-exceedance (mm)											
	0.5		0.75		0.8		0.9		0.99		0.999	
	W	I	W	I	W	I	W	I	W	I	W	I
Restored data	0.09	-	0.58	-	0.87	-	2.32	-	15.67	17.34	47.83	45.85
Original data	0.09	-	0.66	-	1.01	-	2.77	-	19.66	20.91	61.84	63.33

Table 93 Precipitation values given a probability of non-exceedance for Punta Banda station, mean climate, considering all data

Real del Castillo

Real del Castillo restored data


A	0
B	0.4603
C	0.4292
R²	0.9725

Table 94 Mean climate, considering all data, probability of non-exceedance distribution and Weibull parameters for Real del Castillo station restored data

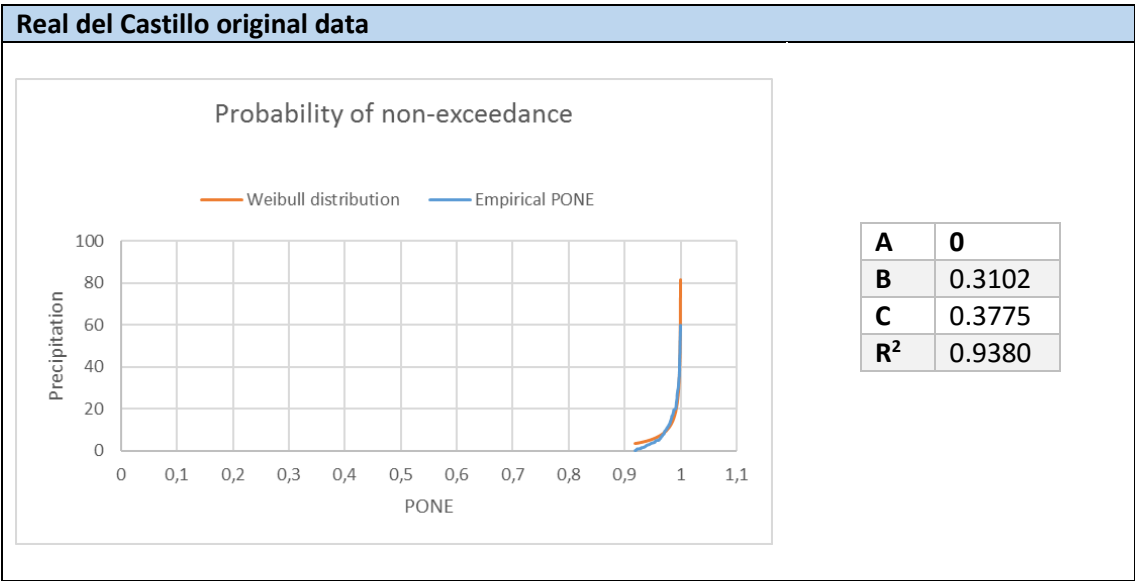


Table 95 Mean climate, considering all data, probability of non-exceedance distribution and Weibull parameters for Real del Castillo station original data

Variable	Precipitation for probability of non-exceedance (mm)											
	0.5		0.75		0.8		0.9		0.99		0.999	
	W	I	W	I	W	I	W	I	W	I	W	I
Restored data	0.20	-	0.99	-	1.39	-	3.24	0.57	16.16	17.35	41.55	44.57
Original data	0.12	-	0.74	-	1.09	-	2.83	-	17.73	19.90	51.91	53.04

Table 96 Precipitation values given a probability of non-exceedance for Real del Castillo station, mean climate, considering all data

San Carlos

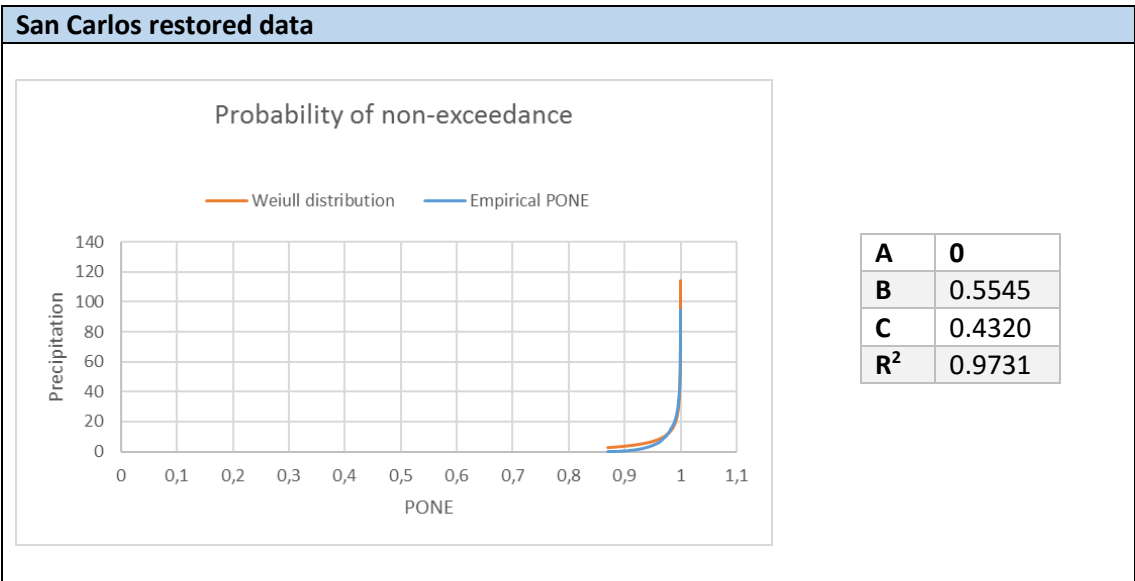


Table 97 Mean climate, considering all data, probability of non-exceedance distribution and Weibull parameters for San Carlos station restored data

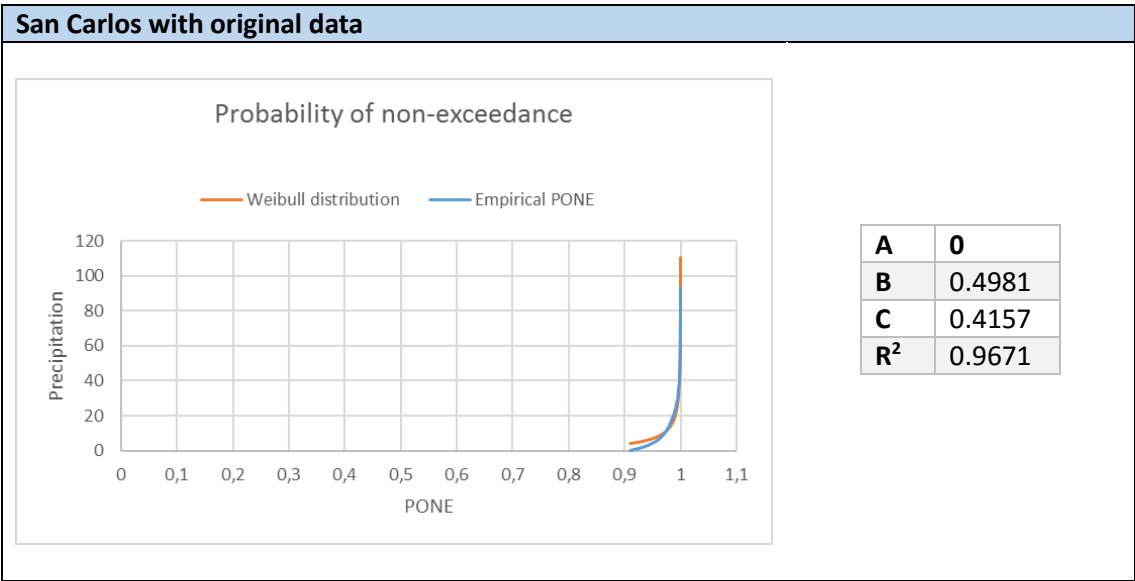


Table 98 Mean climate, considering all data, probability of non-exceedance distribution and Weibull parameters for San Carlos station original data

Variable	Precipitation for probability of non-exceedance (mm)											
	0.5		0.75		0.8		0.9		0.99		0.999	
	W	I	W	I	W	I	W	I	W	I	W	I
Restored data	0.24	-	1.18	-	1.67	-	3.82	0.43	19.02	20.95	48.63	47.1
Original data	0.21	-	1.09	-	1.56	-	3.70	-	19.62	23.14	52.03	51.59

Table 99 Precipitation values given a probability of non-exceedance for San Carlos station, mean climate, considering all data

San Rafael

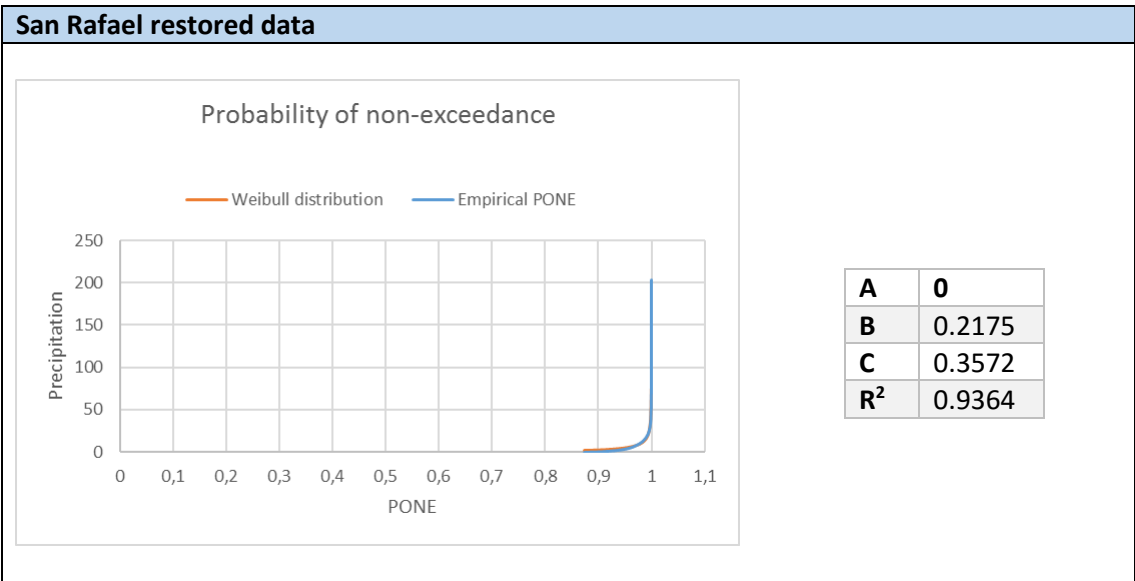


Table 100 Mean climate, considering all data, probability of non-exceedance distribution and Weibull parameters for San Rafael station restored data

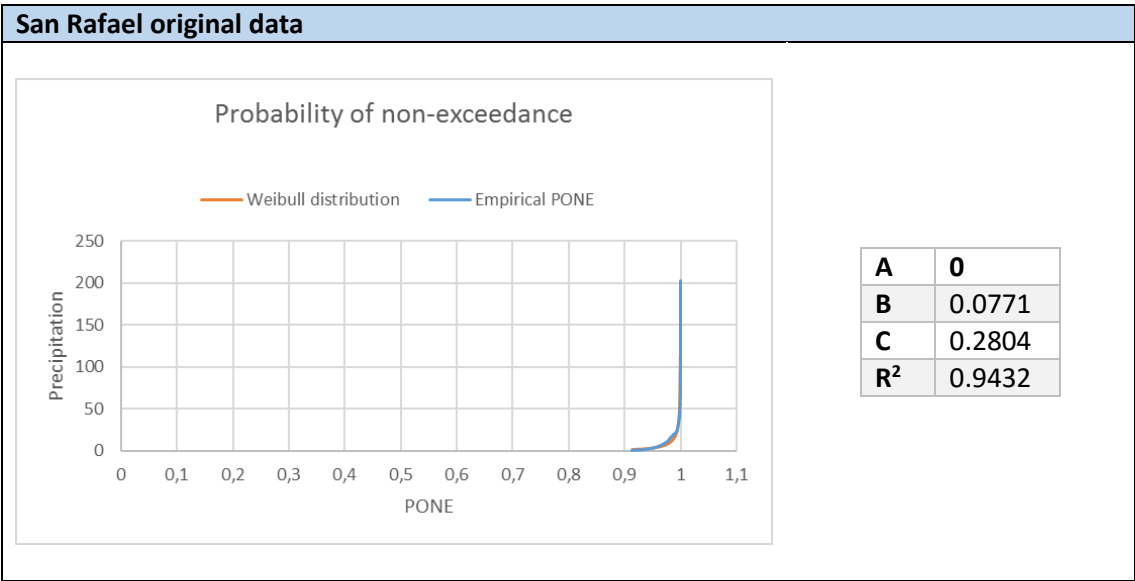


Table 101 Mean climate, considering all data, probability of non-exceedance distribution and Weibull parameters for San Rafael station original data

Variable	Precipitation for probability of non-exceedance (mm)											
	0.5		0.75		0.8		0.9		0.99		0.999	
	W	I	W	I	W	I	W	I	W	I	W	I
Restored data	0.08	-	0.54	-	0.82	-	2.25	0.72	15.64	17.65	48.65	41.29
Original data	0.02	-	0.25	-	0.42	-	1.51	-	17.89	20.72	75.98	59.39

Table 102 Precipitation values given a probability of non-exceedance for San Rafael station, mean climate, considering all data

Santa Isabel

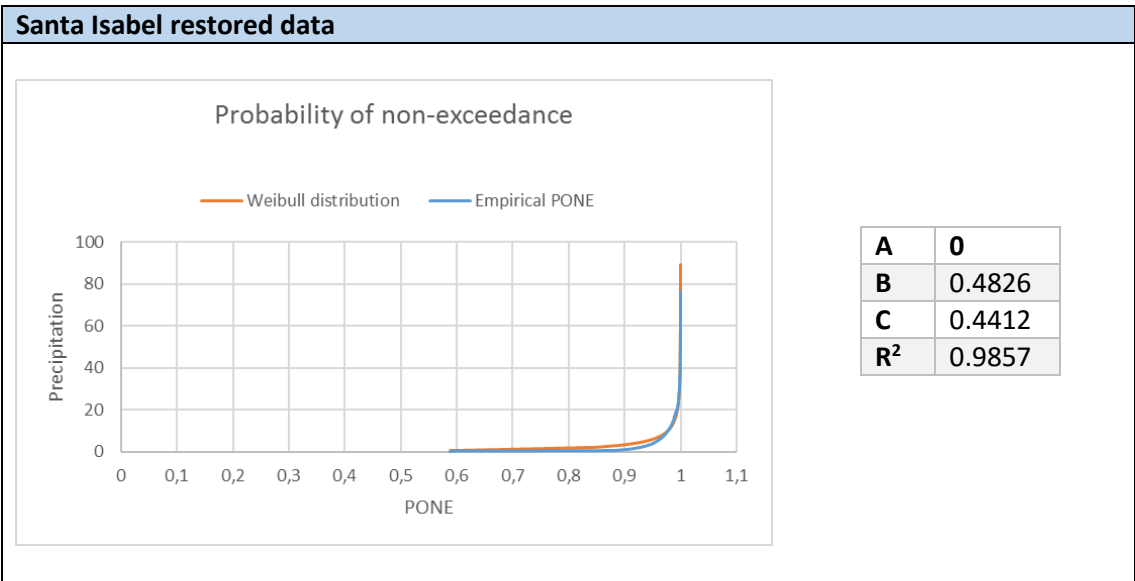
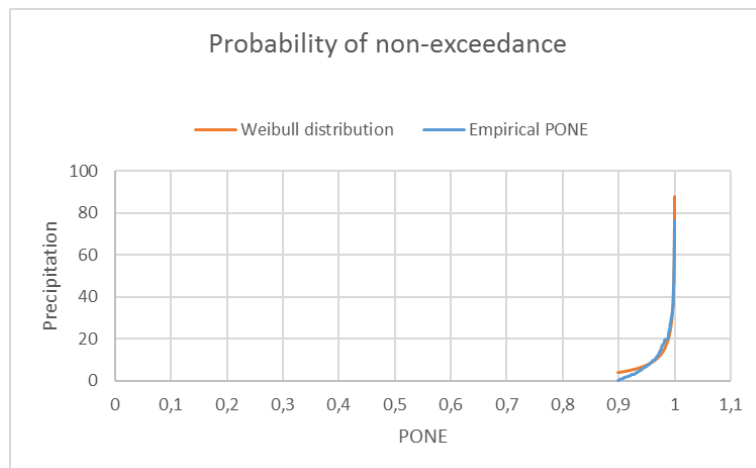


Table 103 Mean climate, considering all data, probability of non-exceedance distribution and Weibull parameters for Santa Isabel station restored data

Santa Isabel original data



A	0
B	0.5131
C	0.4098
R²	0.9772

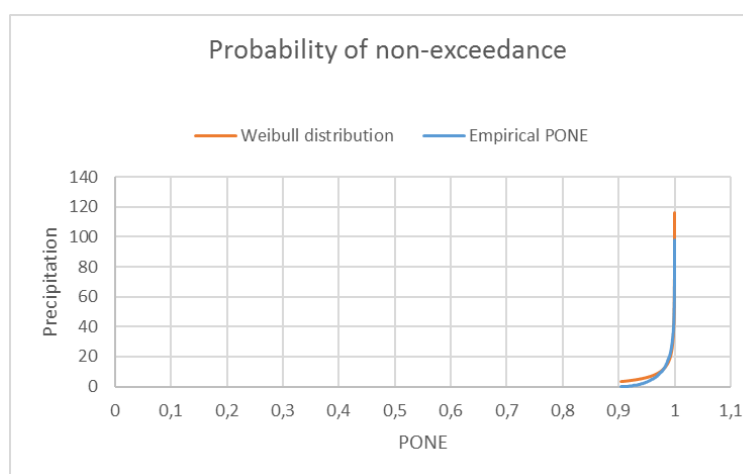
Table 104 Mean climate, considering all data, probability of non-exceedance distribution and Weibull parameters for Santa Isabel station original data

Variable	Precipitation for probability of non-exceedance (mm)											
	0.5		0.75		0.8		0.9		0.99		0.999	
	W	I	W	I	W	I	W	I	W	I	W	I
Restored data	0.21	-	1.01	0.36	1.42	0.38	3.20	0.97	15.38	17.51	38.56	38.13
Original data	0.21	-	1.14	-	1.64	-	3.93	0.12	21.32	23.87	57.34	57.2

Table 105 Precipitation values given a probability of non-exceedance for Santa Isabel station, mean climate, considering all data

Santo Tomás

Santo Tomás restored data



A	0
B	0.4184
C	0.4091
R²	0.9730

Table 106 Mean climate, considering all data, probability of non-exceedance distribution and Weibull parameters for Santo Tomás station restored data

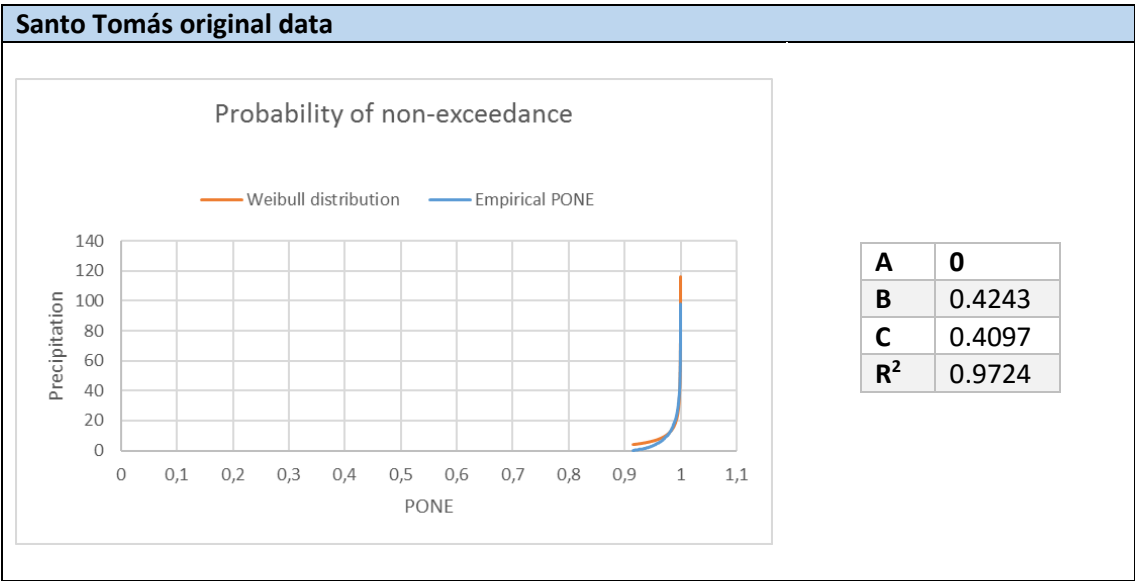


Table 107 Mean climate, considering all data, probability of non-exceedance distribution and Weibull parameters for Santo Tomás station original data

Variable	Precipitation for probability of non-exceedance (mm)											
	0.5		0.75		0.8		0.9		0.99		0.999	
	W	I	W	I	W	I	W	I	W	I	W	I
Restored data	0.17	-	0.93	-	1.34	-	3.21	-	17.48	19.75	47.10	49.06
Original data	0.17	-	0.94	-	1.36	-	3.25	-	17.65	19.86	47.48	49.31

Table 108 Precipitation values given a probability of non-exceedance for Santo Tomás station, mean climate, considering all data

Sierra de Juárez

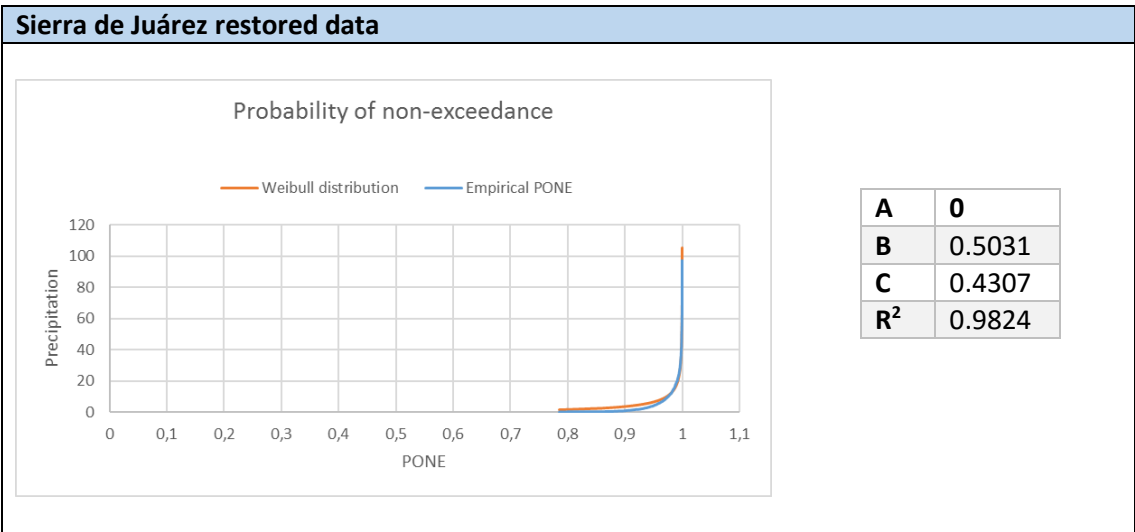
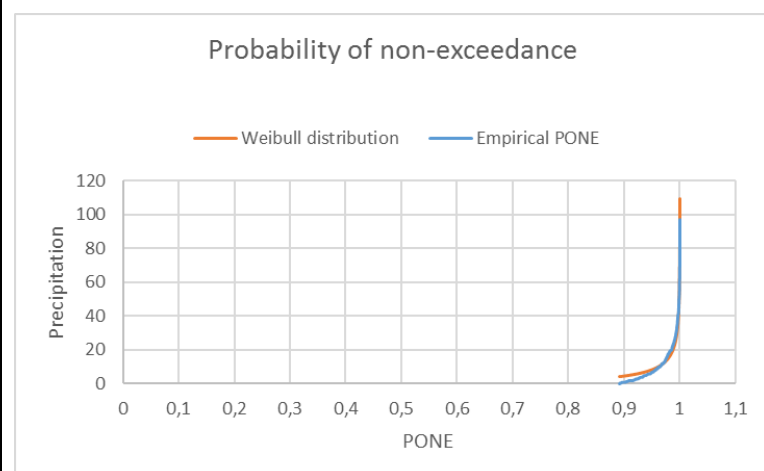


Table 109 Mean climate, considering all data, probability of non-exceedance distribution and Weibull parameters for Sierra de Juárez station restored data

Sierra de Juárez original data

A	0
B	0.6298
C	0.4278
R²	0.9691

Table 110 Mean climate, considering all data, probability of non-exceedance distribution and Weibull parameters for Sierra de Juárez station original data

Variable	Precipitation for probability of non-exceedance (mm)											
	0.5		0.75		0.8		0.9		0.99		0.999	
	W	I	W	I	W	I	W	I	W	I	W	I
Restored data	0.21	-	1.07	-	1.52	0.42	3.49	1.14	17.44	19.21	44.71	45.49
Original data	0.27	-	1.35	-	1.92	-	4.43	0.96	22.37	25.60	57.73	55.69

Table 111 Precipitation values given a probability of non-exceedance for Sierra de Juárez station, mean climate, considering all data

Generally speaking, as can be seen from the graphs and tables 90% of the time the expected precipitation is equal to 0mm, with the exception of the Maneadero, Santa Isabel and Sierra de Juárez stations, where the null precipitation is 80% of the time and 60% of the time, respectively. That was to be expected, as the particular area of study varies between the Mediterranean and arid climates, where rain is scarce.

Regarding the Weibull distribution in itself, it can safely be said that it adjusts very well in all the cases. Namely, up until 0.975 probability of non-exceedance the Weibull adjustments exceed the interpolation values and from that probability of non-exceedance it's vice versa.

As for results of probability of non-exceedance regarding the restored and original data, the results are similar and generally don't vary more than 10%.

Considering only factual precipitation

This part considers only the factual precipitation, that is, all the precipitation values different from 0mm of rainfall.

Tables 112 to 162 show the probability of non-exceedance distribution and Weibull parameters for each station considering restored and original data; also, the comparison between the precipitation values for a given probability of non-exceedance, where the values marked under *W* were obtained using the Weibull distribution formula and those marked under *I* were obtained using linear interpolation between the data and the empirical PONE.

Presa ELZ

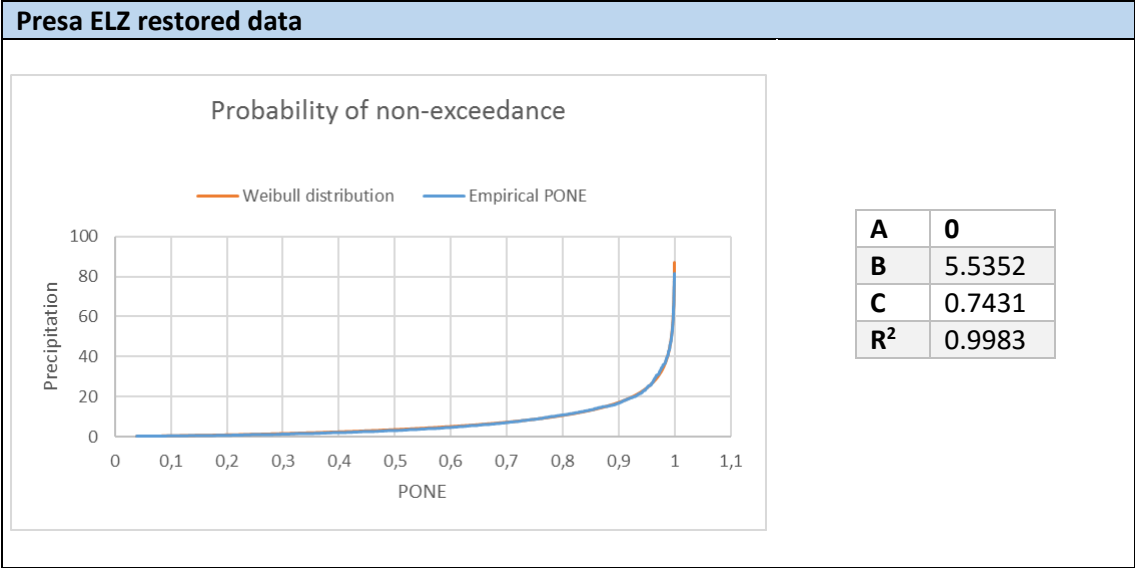
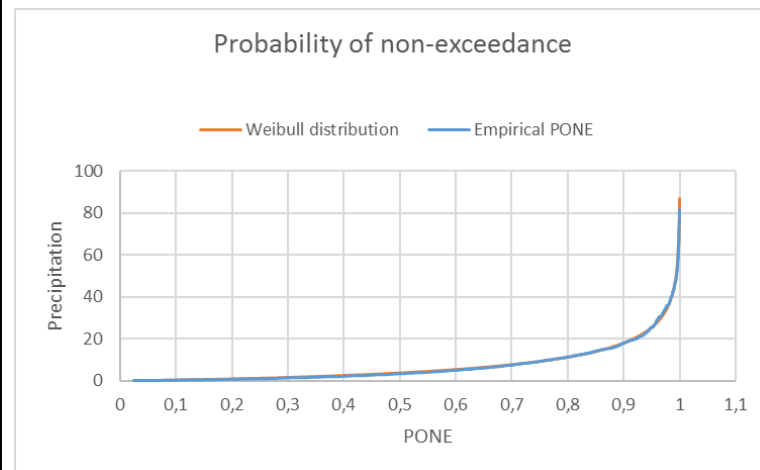


Table 112 Mean climate, considering only precipitation data, probability of non-exceedance distribution and Weibull parameters for Presa ELZ station restored data

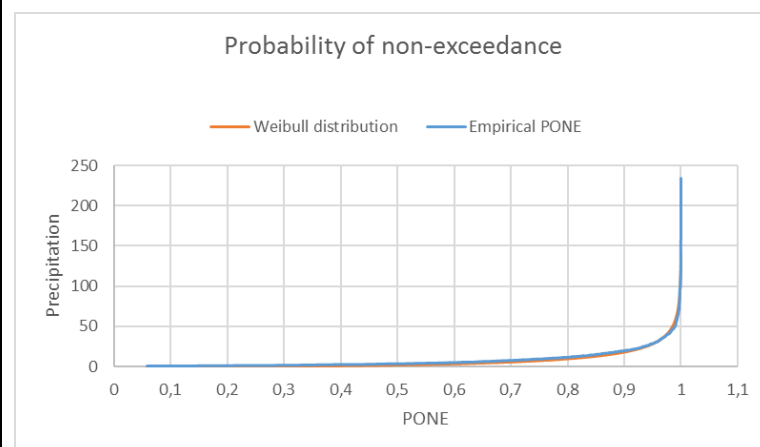
Presa ELZ original data


A	0
B	5.9917
C	0.7585
R²	0.9982

Table 113 Mean climate, considering only precipitation data, probability of non-exceedance distribution and Weibull parameters for Presa ELZ station original data

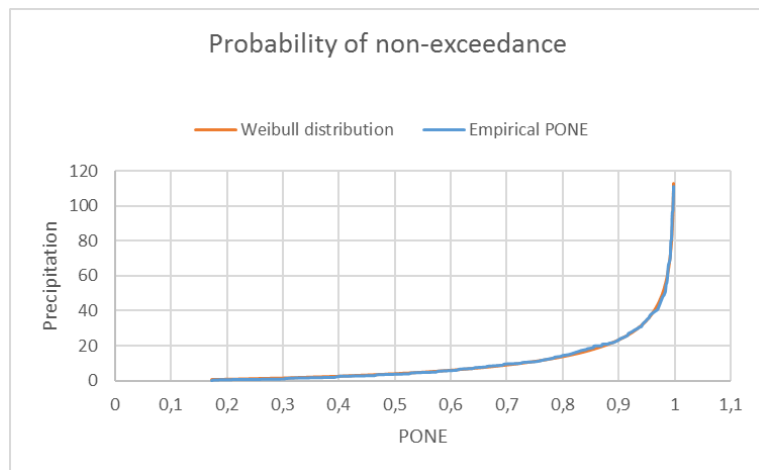
Variable	Precipitation for probability of non-exceedance (mm)											
	0.5		0.75		0.8		0.9		0.99		0.999	
	W	I	W	I	W	I	W	I	W	I	W	I
Restored data	3.38	2.96	8.59	8.62	10.5	10.76	17.01	16.71	43.22	42.98	74.59	75.23
Original data	3.70	3.43	9.22	9.4	11.22	11.43	17.99	17.99	44.87	44.5	76.58	76.82

Table 114 Precipitation values given a probability of non-exceedance for Presa ELZ station, mean climate, considering only precipitation data

Ejido Uruapan
Ejido Uruapan with restored data


A	0
B	4.6165
C	0.5991
R²	0.9374

Table 115 Mean climate, considering only precipitation data, probability of non-exceedance distribution and Weibull parameters for Ejido Uruapan station restored data

Ejido Uruapan with original data

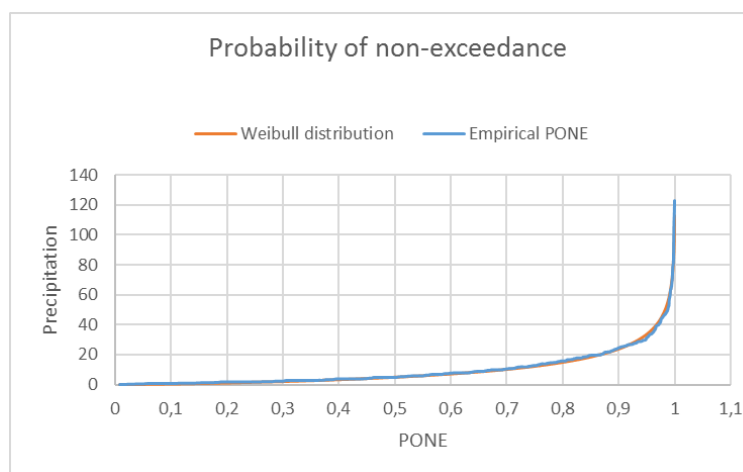
A	0
B	6.7952
C	0.6770
R²	0.9956

Table 116 Mean climate, considering only precipitation data, probability of non-exceedance distribution and Weibull parameters for Ejido Uruapan station original data

Variable	Precipitation for probability of non-exceedance (mm)											
	0.5		0.75		0.8		0.9		0.99		0.999	
	W	I	W	I	W	I	W	I	W	I	W	I
Restored data	2.5	2.96	7.96	8.96	10.22	11	18.57	19.36	59.07	50.92	116.23	117.97
Original data	3.95	3.77	11.01	10.95	13.72	14.45	23.30	23.22	64.86	66.68	118.05	113.48

Table 117 Precipitation values given a probability of non-exceedance for Ejido Uruapan station, mean climate, considering only precipitation data

El Álamo

El Álamo restored data

A	0
B	8.0365
C	0.7644
R²	0.9891

Table 118 Mean climate, considering only precipitation data, probability of non-exceedance distribution and Weibull parameters for El Álamo station restored data

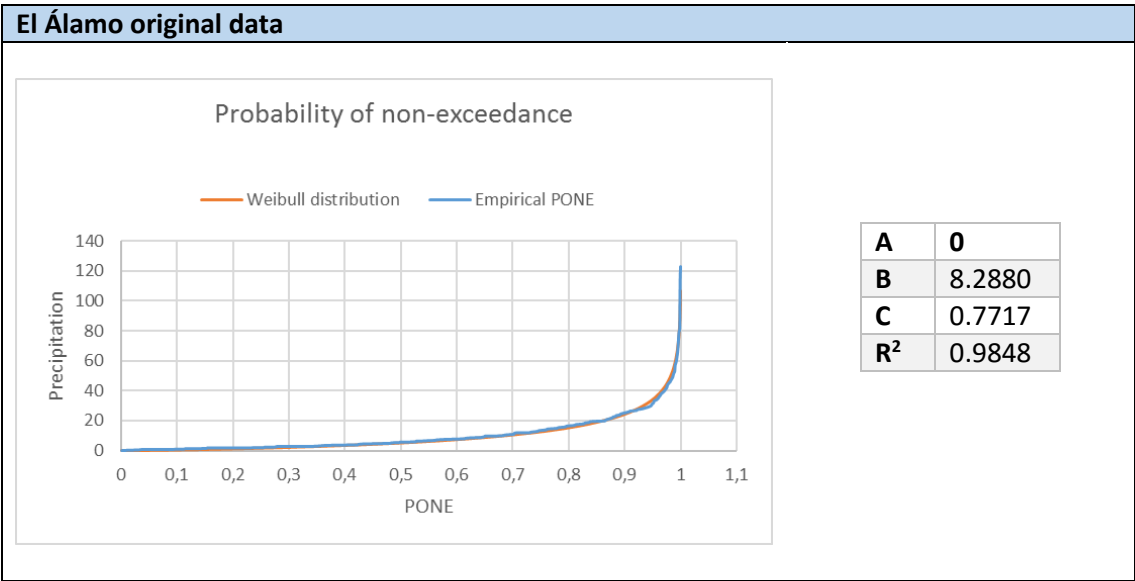


Table 119 Mean climate, considering only precipitation data, probability of non-exceedance distribution and Weibull parameters for El Álamo station original data

Variable	Precipitation for probability of non-exceedance (mm)											
	0.5		0.75		0.8		0.9		0.99		0.999	
	W	I	W	I	W	I	W	I	W	I	W	I
Restored data	4.98	4.99	12.32	12.88	14.98	15.94	23.93	24.71	59.26	57.27	100.72	116.02
Original data	5.15	5.73	12.66	13.63	15.36	16.66	24.43	25.36	59.97	57.81	101.43	120.45

Table 120 Precipitation values given a probability of non-exceedance for El Álamo station, mean climate, considering only precipitation data

El Ciprés

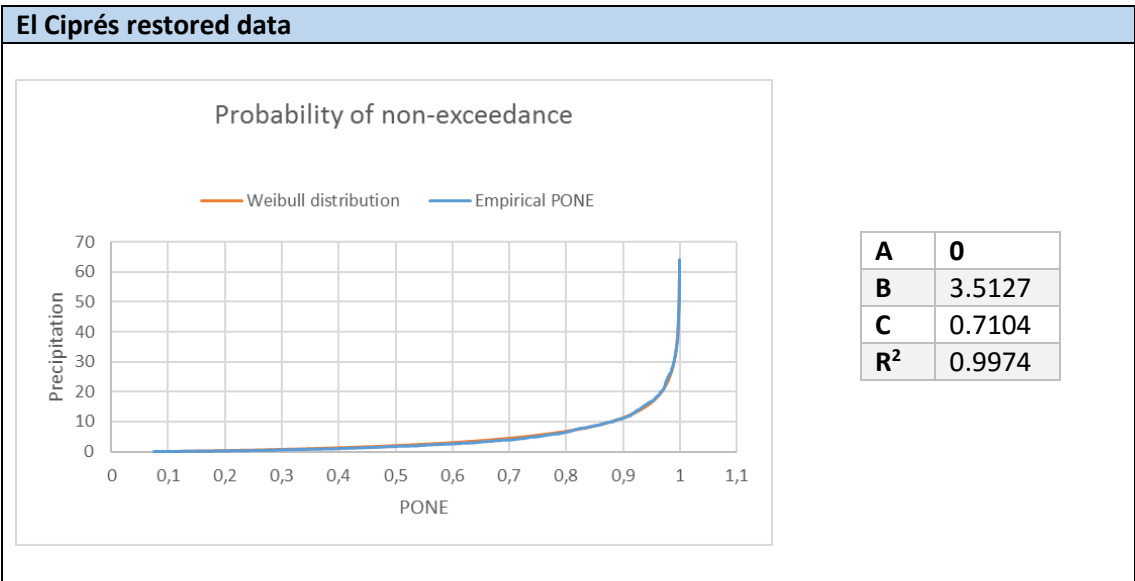


Table 121 Mean climate, considering only precipitation data, probability of non-exceedance distribution and Weibull parameters for El Ciprés station restored data

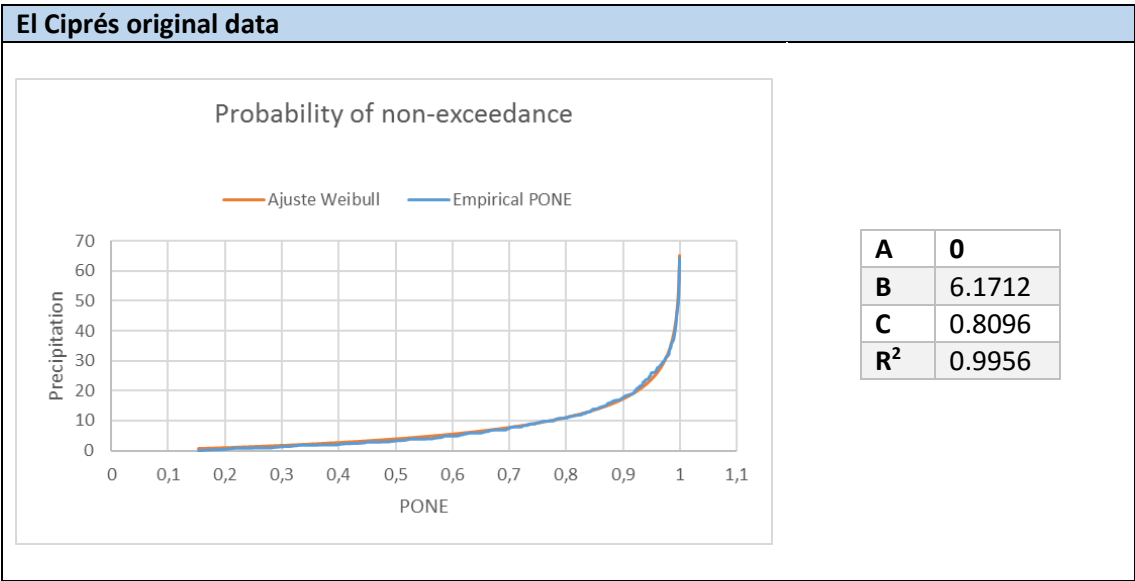


Table 122 Mean climate, considering only precipitation data, probability of non-exceedance distribution and Weibull parameters for El Ciprés station original data

Variable	Precipitation for probability of non-exceedance (mm)											
	0.5		0.75		0.8		0.9		0.99		0.999	
	W	I	W	I	W	I	W	I	W	I	W	I
Restored data	2.10	1.83	5.56	5.08	6.68	6.61	11.36	11.16	30.15	30.17	53.35	51.05
Original data	3.92	3.34	9.24	9.39	11.11	10.98	17.29	17.83	40.70	39.03	67.16	65.72

Table 123 Precipitation values given a probability of non-exceedance for El Ciprés station, mean climate, considering only precipitation data

El Farito

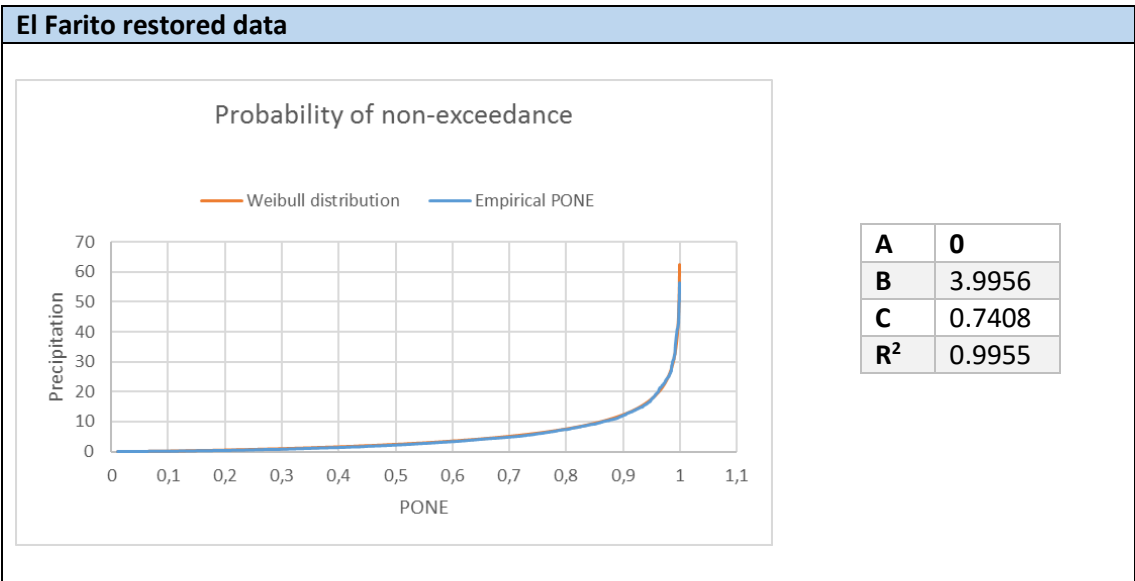
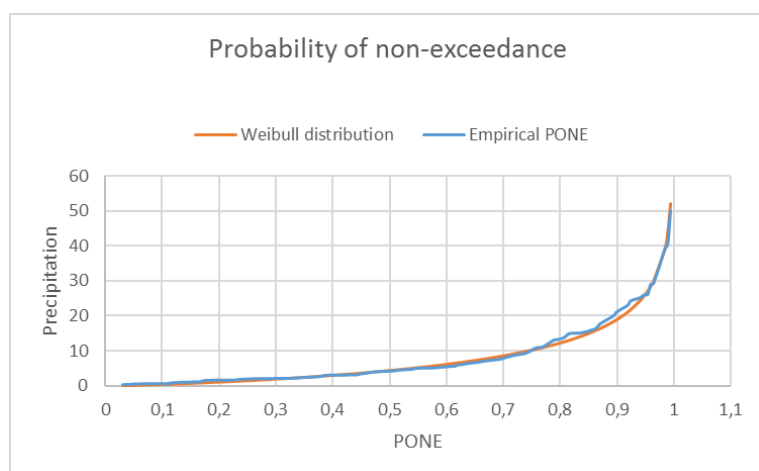


Table 124 Mean climate, considering only precipitation data, probability of non-exceedance distribution and Weibull parameters for El Farito station restored data

El Farito original data



A	0
B	6.8806
C	0.8234
R²	0.9915

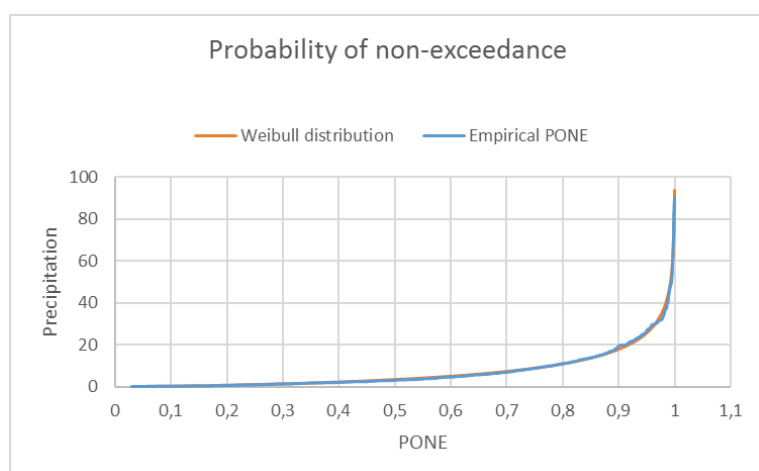
Table 125 Mean climate, considering only precipitation data, probability of non-exceedance distribution and Weibull parameters for El Farito station original data

Variable	Precipitation for probability of non-exceedance (mm)											
	0.5		0.75		0.8		0.9		0.99		0.999	
	W	I	W	I	W	I	W	I	W	I	W	I
Restored data	2.44	2.28	6.21	6.07	7.6	7.5	12.32	12.15	31.4	31.92	54.27	50.09
Original data	4.41	4.07	10.23	10	12.26	13.3	18.95	21	43.97	40.5	71.95	57.6

Table 126 Precipitation values given a probability of non-exceedance for El Farito station, mean climate, considering only precipitation data

Héroes de la Independencia

Héroes de la Independencia restored data



A	0
B	5.6711
C	0.7254
R²	0.9911

Table 127 Mean climate, considering only precipitation data, probability of non-exceedance distribution and Weibull parameters for Héroes de la Independencia station restored data

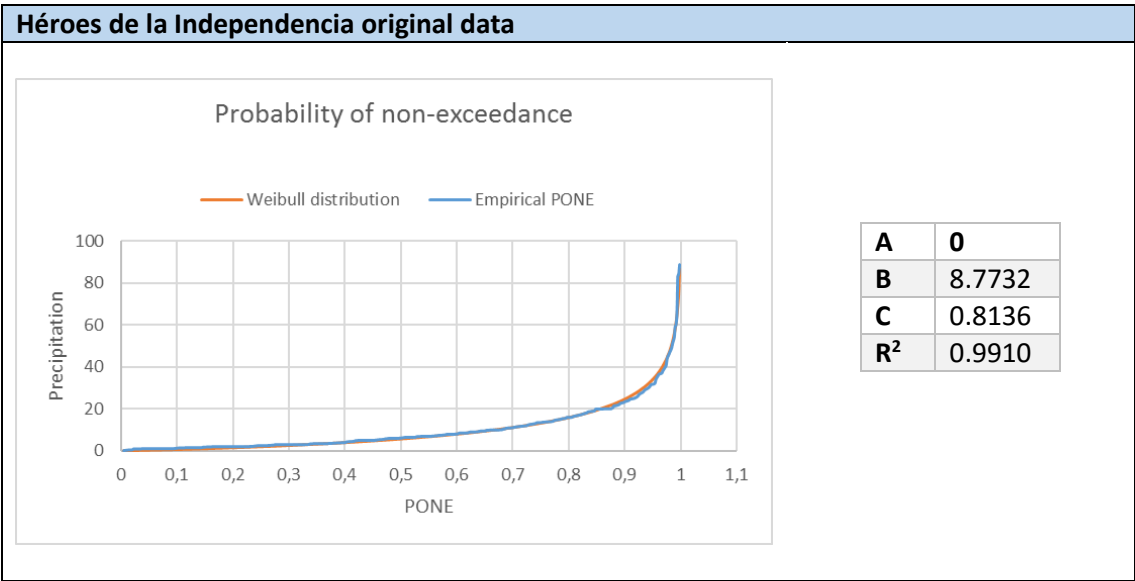


Table 128 Mean climate, considering only precipitation data, probability of non-exceedance distribution and Weibull parameters for Héroes de la Independencia station original data

Variable	Precipitation for probability of non-exceedance (mm)											
	0.5		0.75		0.8		0.9		0.99		0.999	
	W	I	W	I	W	I	W	I	W	I	W	I
Restored data	3.42	3.07	8.9	8.92	10.93	11.01	17.9	19.54	46.55	45.3	81.41	88.24
Original data	5.59	6.05	13.11	13.48	15.75	15.94	24.45	23.27	57.33	57.55	94.36	90.31

Table 129 Precipitation values given a probability of non-exceedance for Héroes de la Independencia station, mean climate, considering only precipitation data

La Bocana

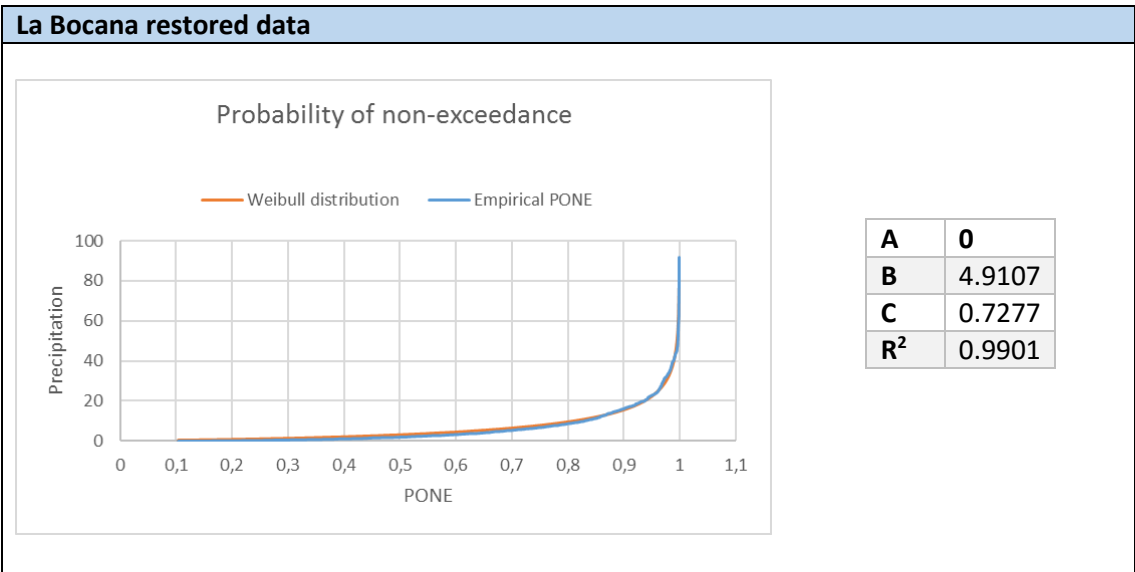


Table 130 Mean climate, considering only precipitation data, probability of non-exceedance distribution and Weibull parameters for La Bocana station restored data

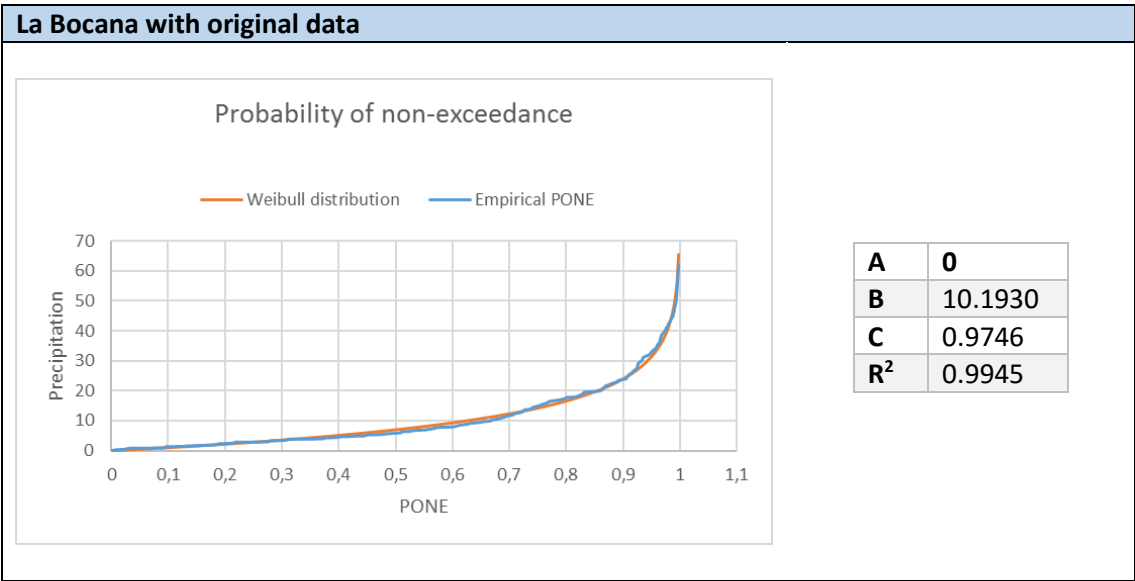


Table 131 Mean climate, considering only precipitation data, probability of non-exceedance distribution and Weibull parameters for La Bocana station original data

Variable	Precipitation for probability of non-exceedance (mm)											
	0.5		0.75		0.8		0.9		0.99		0.999	
	W	I	W	I	W	I	W	I	W	I	W	I
Restored data	2.97	2.13	7.69	6.94	9.44	8.81	15.45	16.23	40.05	40.59	69.92	64.48
Original data	7	5.9	14.25	14.93	16.61	17.62	23.99	23.81	48.85	46.74	74.05	65.76

Table 132 Precipitation values given a probability of non-exceedance for La Bocana station, mean climate, considering only precipitation data

Maneadero

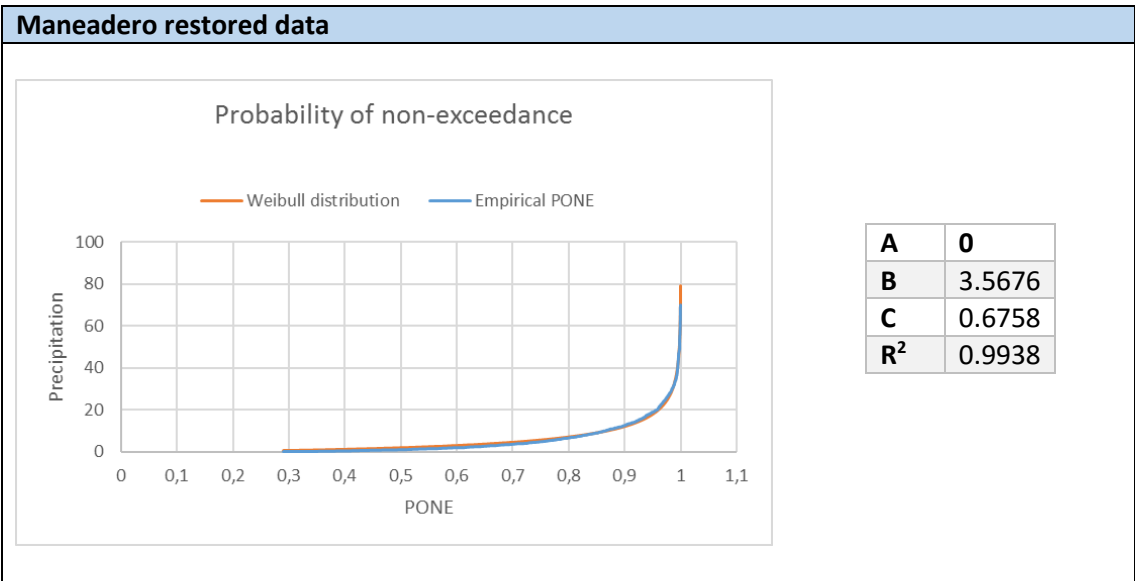
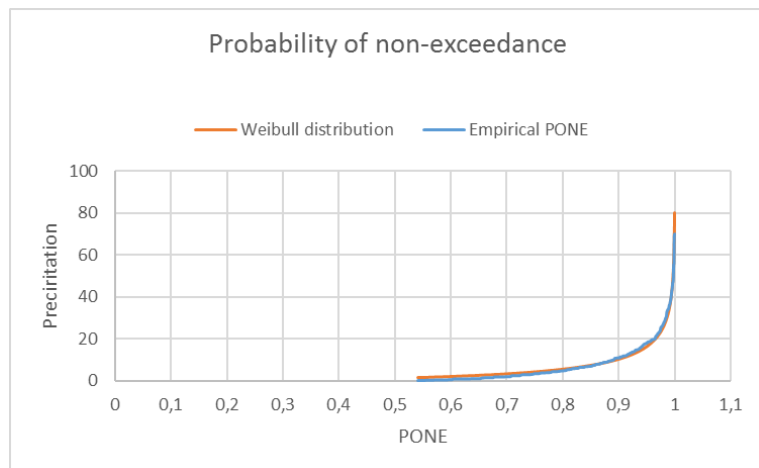


Table 133 Mean climate, considering only precipitation data, probability of non-exceedance distribution and Weibull parameters for Maneadero station restored data

Maneadero with original data

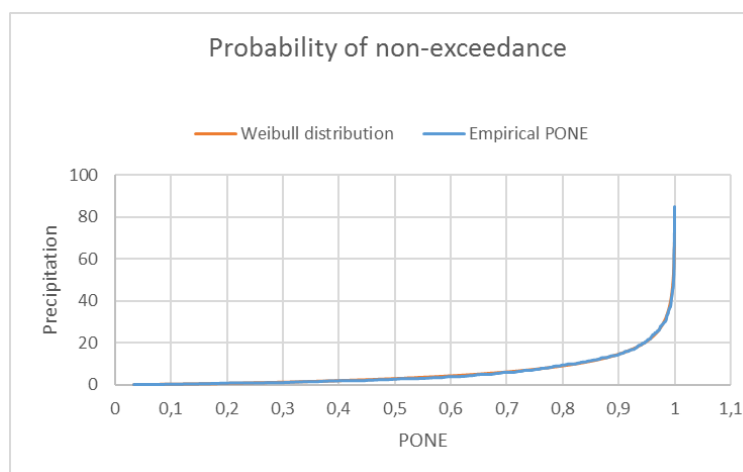
A	0
B	2.4621
C	0.5775
R²	0.9897

Table 134 Mean climate, considering only precipitation data, probability of non-exceedance distribution and Weibull parameters for Maneadero station original data

Variable	Precipitation for probability of non-exceedance (mm)											
	0.5		0.75		0.8		0.9		0.99		0.999	
	W	I	W	I	W	I	W	I	W	I	W	I
Restored data	2.07	0.99	5.78	4.83	7.21	6.64	12.26	12.58	34.18	33.71	62.27	60.14
Original data	1.31	-	4.33	3.41	5.61	4.8	10.44	10.96	34.66	36.10	69.95	69.24

Table 135 Precipitation values given a probability of non-exceedance for Maneadero station, mean climate, considering only precipitation data

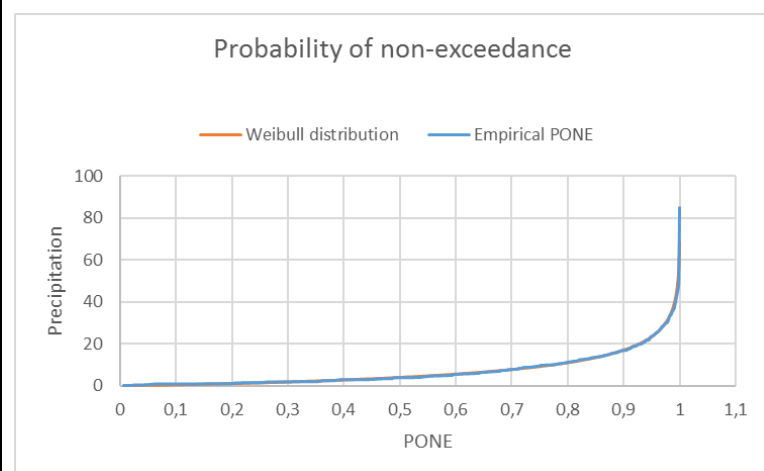
Ojos Negros

Ojos Negros restored data

A	0
B	4.7594
C	0.7466
R²	0.9943

Table 136 Mean climate, considering only precipitation data, probability of non-exceedance distribution and Weibull parameters for Ojos Negros station restored data

Ojos Negros original data



A	0
B	6.1487
C	0.8203
R²	0.9842

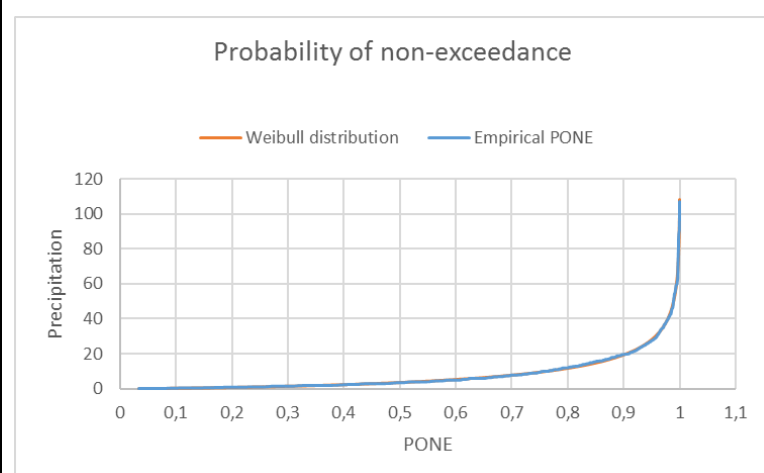
Table 137 Mean climate, considering only precipitation data, probability of non-exceedance distribution and Weibull parameters for Ojos Negros station original data

Variable	Precipitation for probability of non-exceedance (mm)											
	0.5		0.75		0.8		0.9		0.99		0.999	
	W	I	W	I	W	I	W	I	W	I	W	I
Restored data	2.91	2.72	7.37	7.3	9.00	9.44	14.55	14.47	36.81	36.2	63.36	66.26
Original data	3.93	3.92	9.16	9.65	10.98	11.3	17.00	16.9	39.57	37.4	64.86	78.52

Table 138 Precipitation values given a probability of non-exceedance for Ojos Negros station, mean climate, considering only precipitation data

Olivares Mexicanos

Olivares Mexicanos restored data



A	0
B	5.9888
C	0.7074
R²	0.9967

Table 139 Mean climate, considering only precipitation data, probability of non-exceedance distribution and Weibull parameters for Olivares Mexicanos station restored data

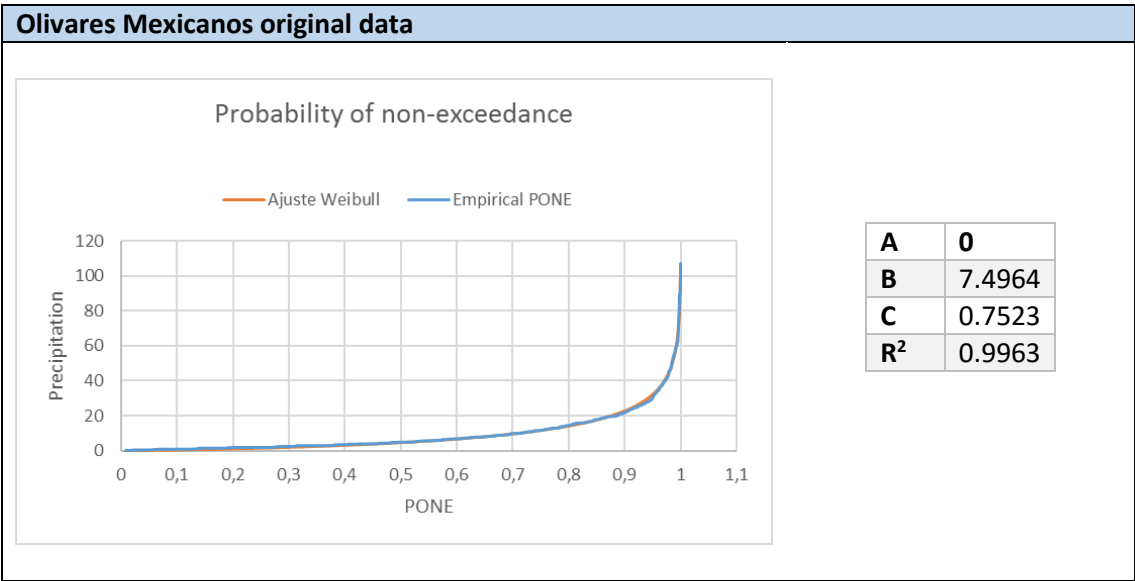


Table 140 Mean climate, considering only precipitation data, probability of non-exceedance distribution and Weibull parameters for Olivares Mexicanos station original data

Variable	Precipitation for probability of non-exceedance (mm)											
	0.5		0.75		0.8		0.9		0.99		0.999	
	W	I	W	I	W	I	W	I	W	I	W	I
Restored data	3.57	3.46	9.50	9.48	11.74	12	19.47	19.64	51.87	53.42	92.00	90.66
Original data	4.61	4.88	11.57	11.78	14.11	14.63	22.71	21.88	57.07	57.91	97.83	98.86

Table 141 Precipitation values given a probability of non-exceedance for Olivares Mexicanos station, mean climate, considering only precipitation data

Punta Banda

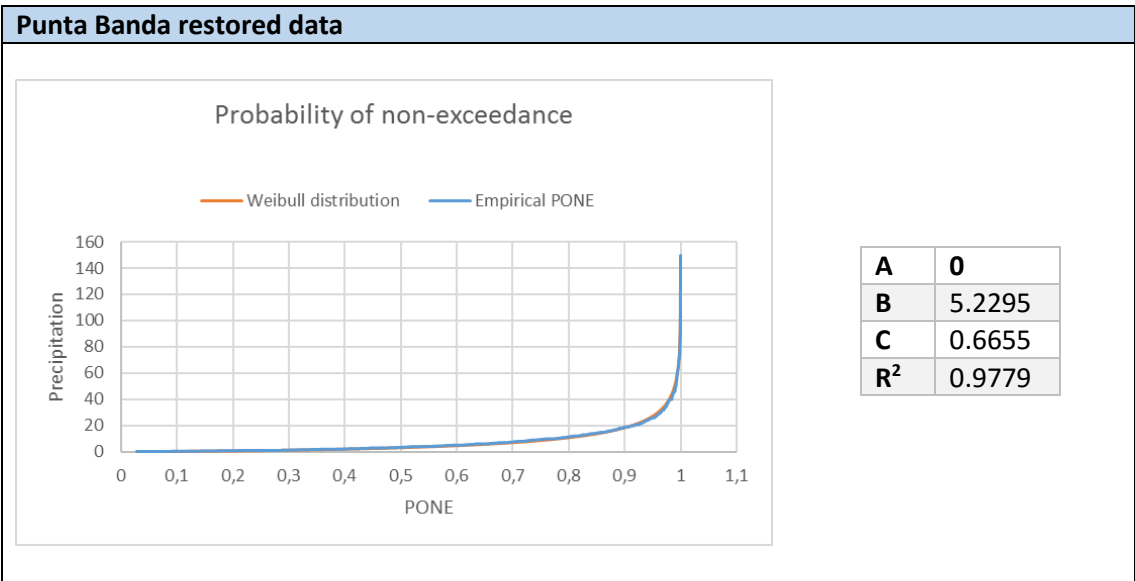


Table 142 Mean climate, considering only precipitation data, probability of non-exceedance distribution and Weibull parameters for Punta Banda station restored data

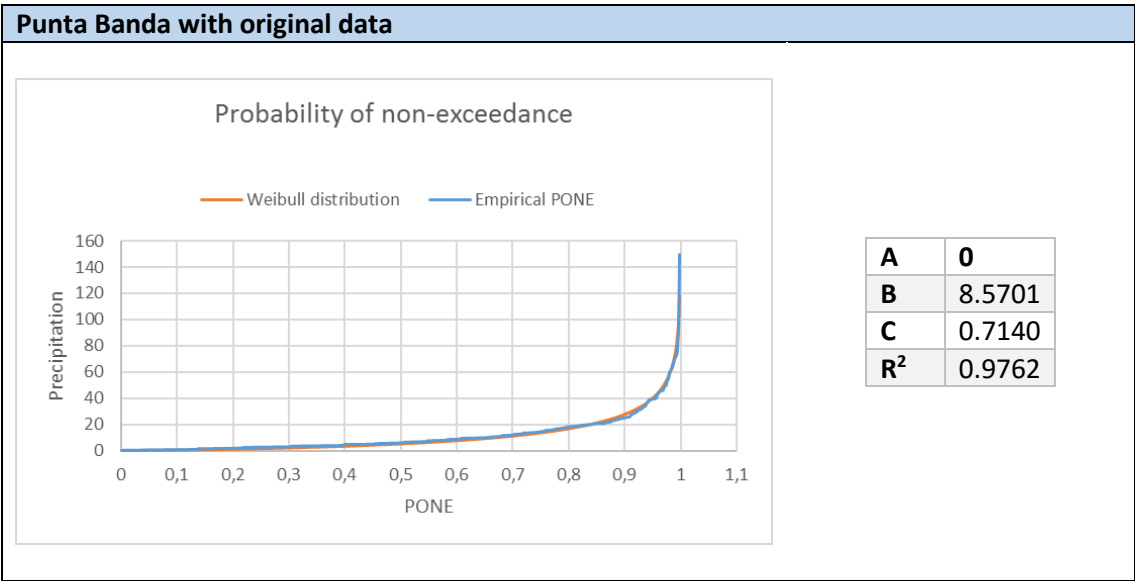


Table 143 Mean climate, considering only precipitation data, probability of non-exceedance distribution and Weibull parameters for Punta Banda station original data

Variable	Precipitation for probability of non-exceedance (mm)											
	0.5		0.75		0.8		0.9		0.99		0.999	
	W	I	W	I	W	I	W	I	W	I	W	I
Restored data	3.01	3.39	8.54	9.39	10.69	11.44	18.31	18.91	51.89	48.14	95.43	102.85
Original data	5.13	5.97	13.54	14.59	16.69	18.33	27.56	25.23	72.76	70.38	128.39	166.90

Table 144 Precipitation values given a probability of non-exceedance for Punta Banda station, mean climate, considering only precipitation data

Real del Castillo

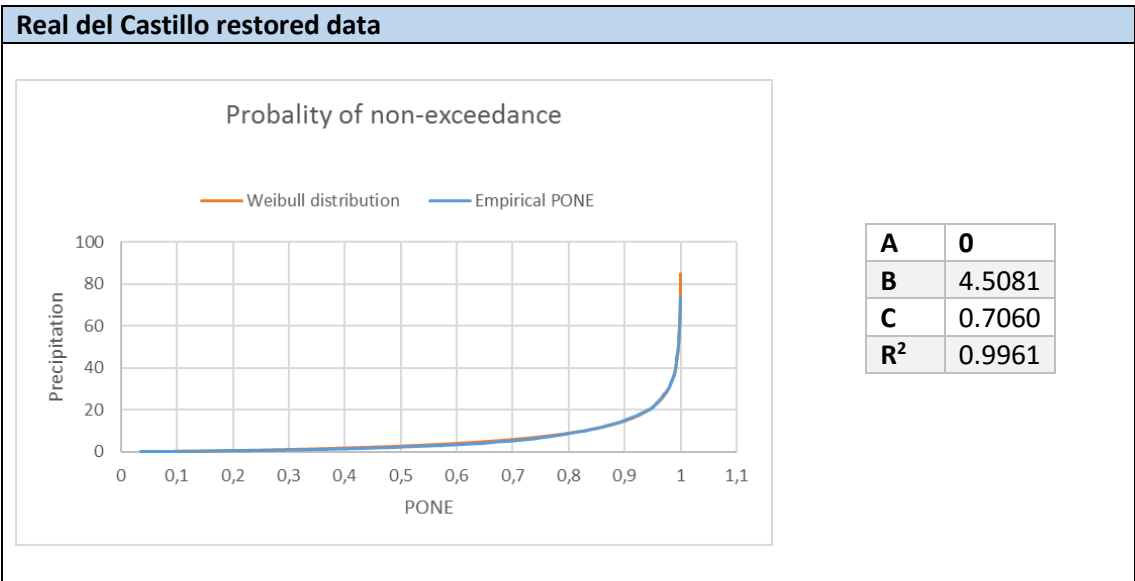


Table 145 Mean climate, considering only precipitation data, probability of non-exceedance distribution and Weibull parameters for Real del Castillo station restored data

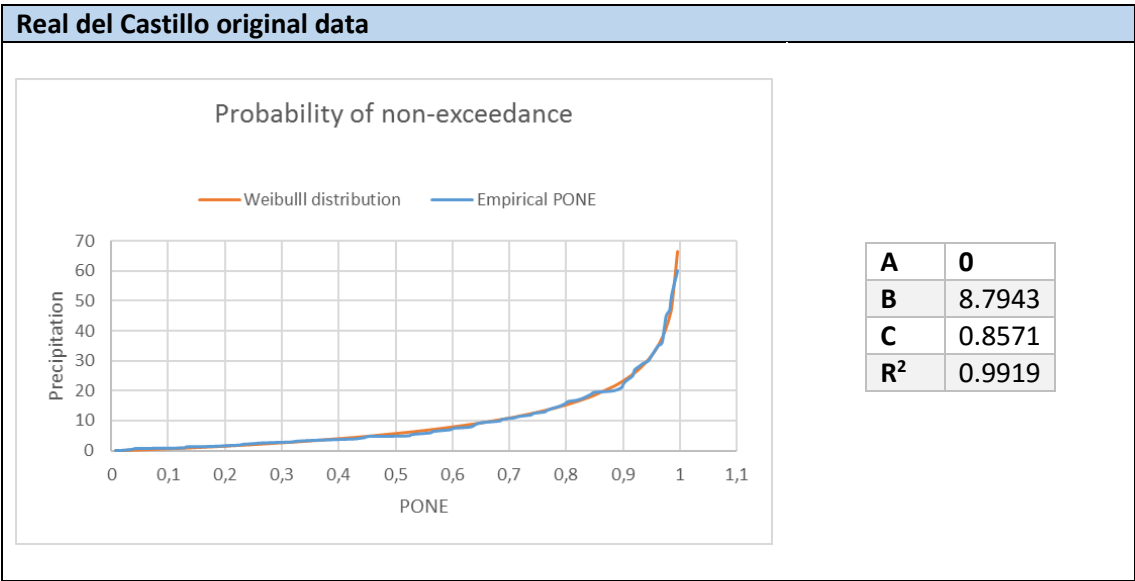


Table 146 Mean climate, considering only precipitation data, probability of non-exceedance distribution and Weibull parameters for San Carlos station original data

Variable	Precipitation for probability of non-exceedance (mm)											
	0.5		0.75		0.8		0.9		0.99		0.999	
	W	I	W	I	W	I	W	I	W	I	W	I
Restored data	2.68	2.26	7.16	6.7	8.85	8.7	14.69	14.98	39.21	37.93	69.63	67.9
Original data	5.73	4.94	12.87	12.69	15.32	15.93	23.27	21.90	52.24	54.91	83.84	61.89

Table 147 Precipitation values given a probability of non-exceedance for Real del Castillo station, mean climate, considering only precipitation data

San Carlos

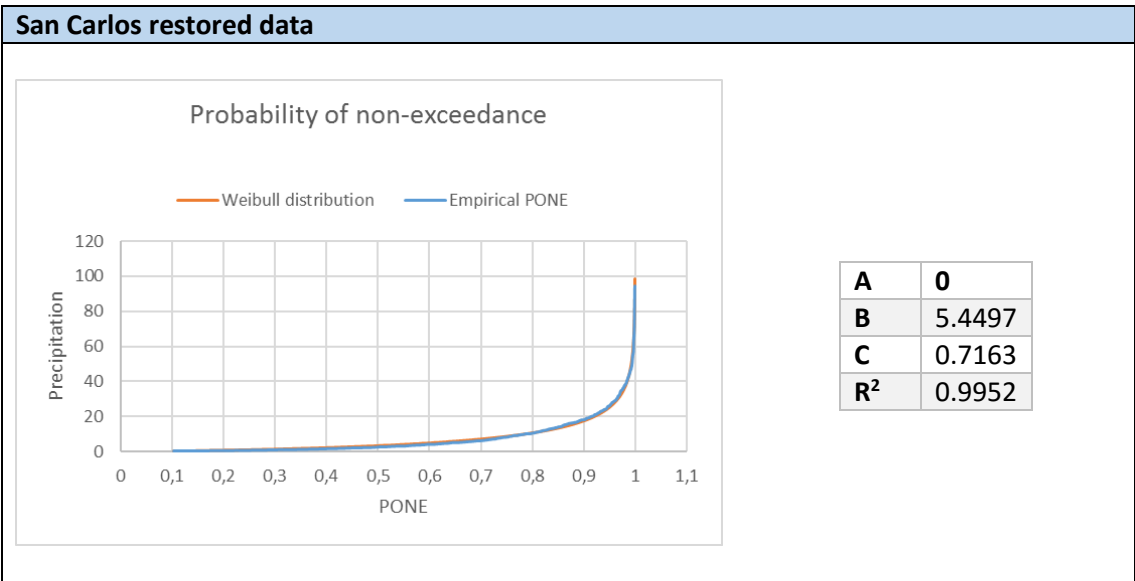


Table 148 Mean climate, considering only precipitation data, probability of non-exceedance distribution and Weibull parameters for San Carlos station restored data

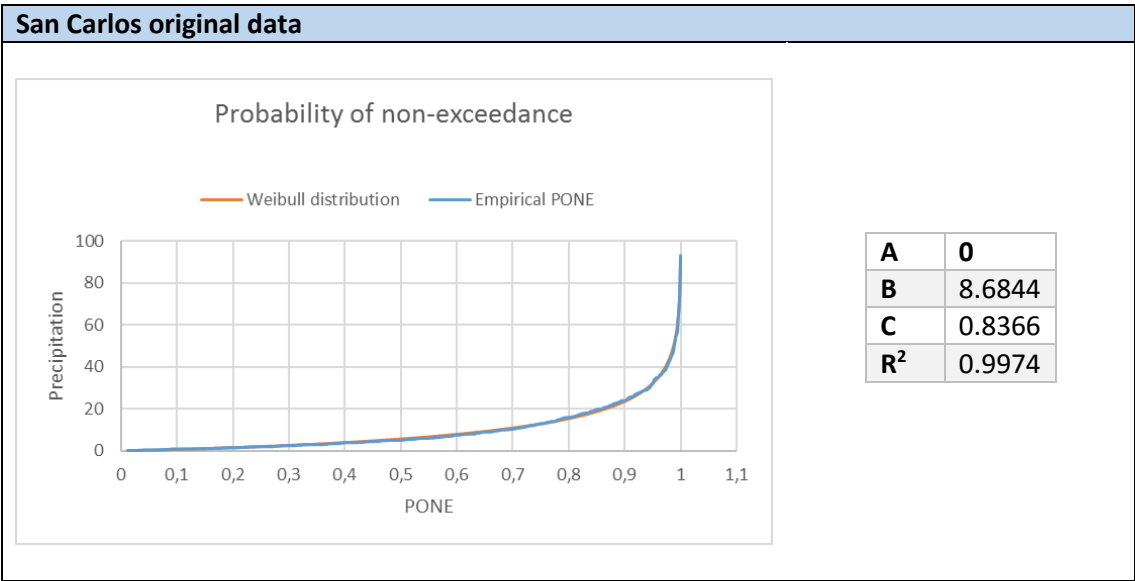


Table 149 Mean climate, considering only precipitation data, probability of non-exceedance distribution and Weibull parameters for San Carlos station original data

Variable	Precipitation for probability of non-exceedance (mm)											
	0.5		0.75		0.8		0.9		0.99		0.999	
	W	I	W	I	W	I	W	I	W	I	W	I
Restored data	3.27	2.35	8.60	8	10.59	10.24	17.46	17.96	45.95	45.23	80.93	85.76
Original data	5.60	5	12.83	12.87	15.34	15.95	23.54	23.99	53.90	53.48	87.51	91.84

Table 150 Precipitation values given a probability of non-exceedance for San Carlos station, mean climate, considering only precipitation data

San Rafael

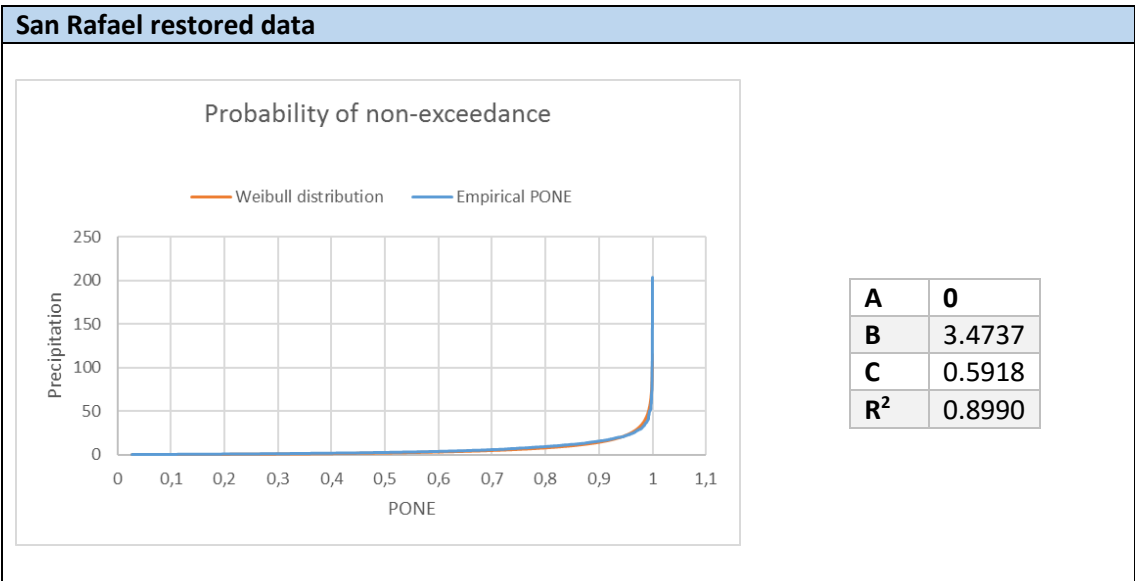
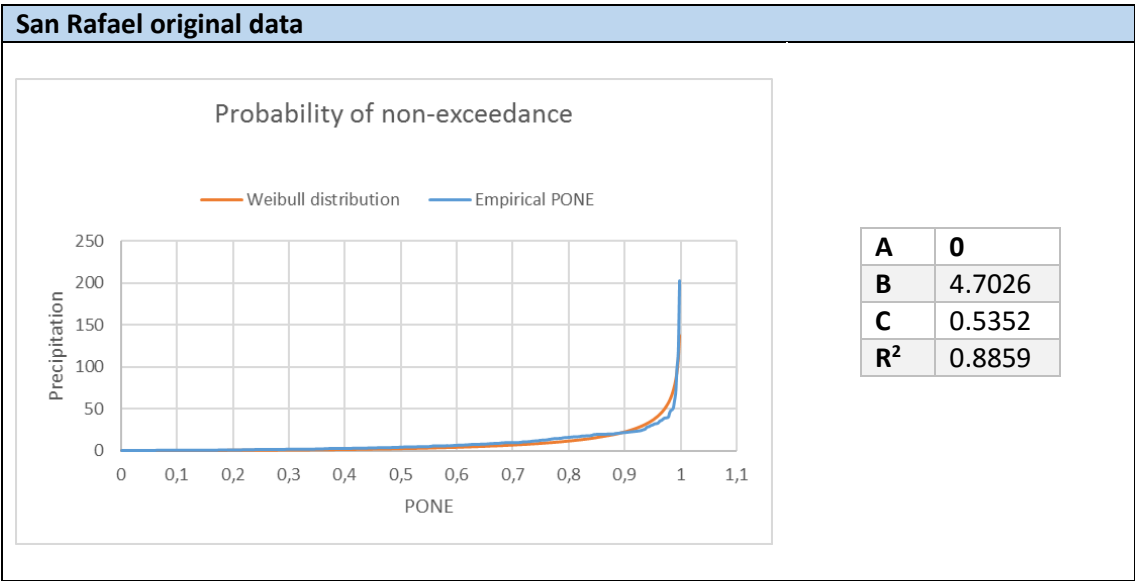
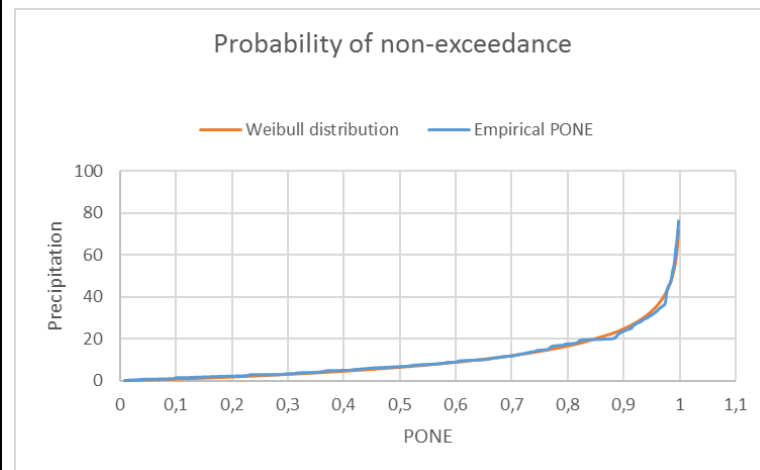


Table 151 Mean climate, considering only precipitation data, probability of non-exceedance distribution and Weibull parameters for San Rafael station restored data



Santa Isabel original data



A	0
B	9.7212
C	0.8906
R²	0.9914

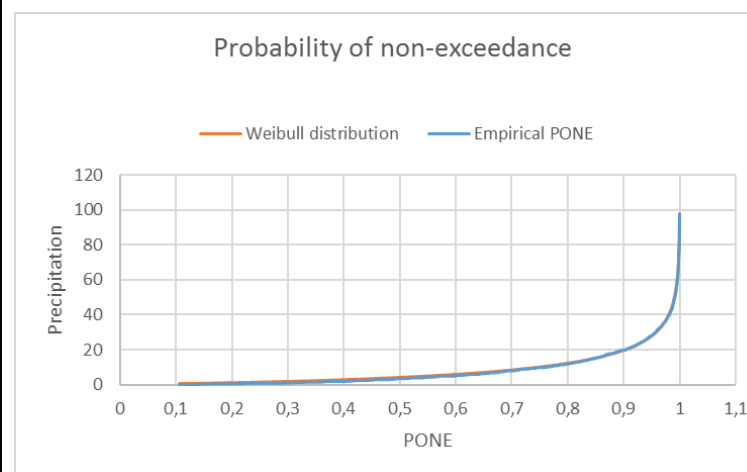
Table 155 Mean climate, considering only precipitation data, probability of non-exceedance distribution and Weibull parameters for Santa Isabel station original data

Variable	Precipitation for probability of non-exceedance (mm)											
	0.5		0.75		0.8		0.9		0.99		0.999	
	W	I	W	I	W	I	W	I	W	I	W	I
Restored data	0.65	0.38	2.42	0.91	3.21	1.54	6.31	5.17	23.41	23.47	50.41	52.5
Original data	6.44	6.79	14.03	14.63	16.59	17.61	24.8	23.77	54	56.99	85.14	81.31

Table 156 Precipitation values given a probability of non-exceedance for Santa Isabel station, mean climate, considering only precipitation data

Santo Tomás

Santo Tomás restored data



A	0
B	6.3740
C	0.7463
R²	0.9989

Table 157 Mean climate, considering only precipitation data, probability of non-exceedance distribution and Weibull parameters for Santo Tomás station restored data

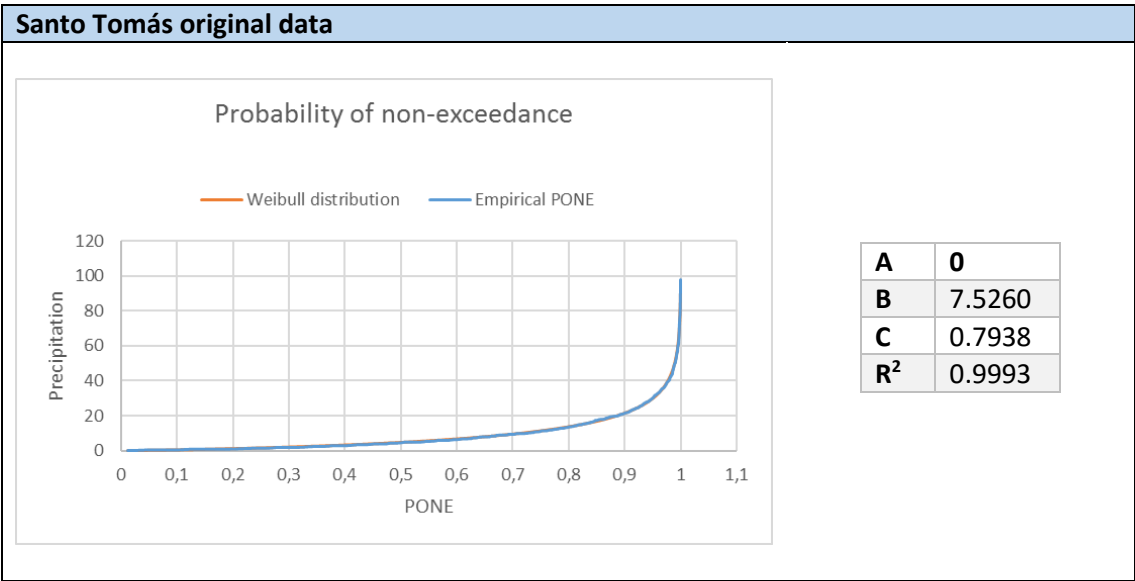


Table 158 Mean climate, considering only precipitation data, probability of non-exceedance distribution and Weibull parameters for Santo Tomás station original data

Variable	Precipitation for probability of non-exceedance (mm)											
	0.5		0.75		0.8		0.9		0.99		0.999	
	W	I	W	I	W	I	W	I	W	I	W	I
Restored data	3.90	3.45	9.87	9.92	12.06	11.97	19.49	19.9	49.33	49.42	84.92	82.86
Original data	4.74	4.65	11.36	11.33	13.71	13.67	21.52	21.55	51.53	50.46	85.88	86.18

Table 159 Precipitation values given a probability of non-exceedance for Santo Tomás station, mean climate, considering only precipitation data

Sierra de Juárez

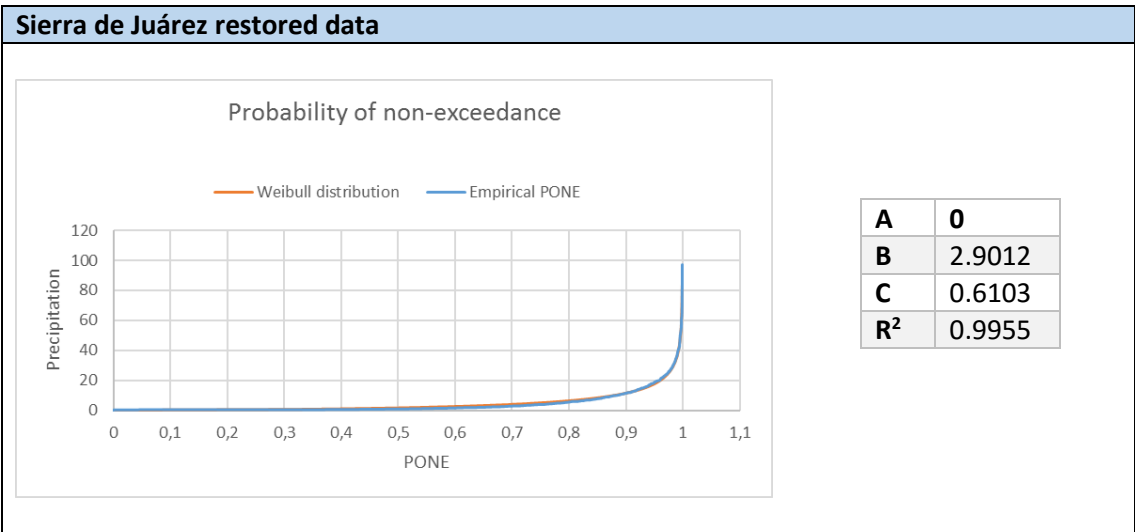
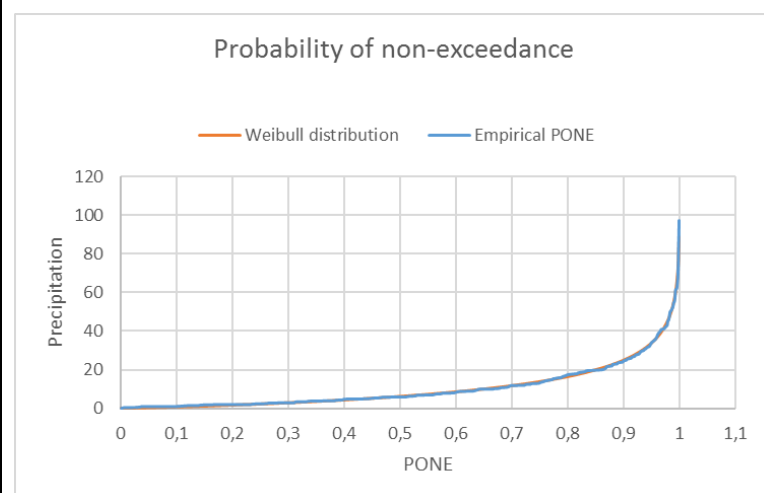


Table 160 Mean climate, considering only precipitation data, probability of non-exceedance distribution and Weibull parameters for Sierra de Juárez station restored data

Sierra de Juárez original data

A	0
B	9.4341
C	0.8583
R²	0.9971

Table 161 Mean climate, considering only precipitation data, probability of non-exceedance distribution and Weibull parameters for Sierra de Juárez station original data

Variable	Precipitation for probability of non-exceedance (mm)											
	0.5		0.75		0.8		0.9		0.99		0.999	
	W	I	W	I	W	I	W	I	W	I	W	I
Restored data	1.59	0.97	4.95	3.93	6.33	5.51	11.38	11.41	35.43	36.01	68.86	63.46
Original data	6.16	5.95	13.80	13.25	16.42	17.40	24.93	24.62	55.90	54.90	89.66	98.06

Table 162 Precipitation values given a probability of non-exceedance for Sierra de Juárez station, mean climate, considering only precipitation data

As can be seen in the graphs the data adjusts extremely well to the Weibull distribution. In some cases, as Ojos Negros, Real del Castillo or Sierra de Juárez stations, among others, it is practically impossible to distinguish the two different representations of the graphs.

Generally, the probabilities of non-exceedance for original and restored data do not vary much either. So it can be safely concluded that the restoration and the characterization of the catchment area are valid.

Seasonal and monthly Mann-Kendall trend tests

In this chapter, prior to the correlation with the climate indexes, it was deemed necessary to look at the way the precipitation changed through the 59 available years of data.

For that, the restored data was segregated into the “Season by Year” and “Month by Year” sections, taking into account the mean and the maximum values of each set. For each set of data, that is seasonal (springs, summers, autumns and winters) and monthly (Januaries,

Februaries, Marchs, Aprils, Mays, Junes, Julys, Augusts, Septembers, Octobers, Novembers and Decembers), a Mann-Kendall trend test was run.

In statistical terms, the Mann-Kendall test determines whether the probability distribution from which the data arises has changed over time. Also, it describes the amount or rate of the change.

For all the instances the Mann-Kendall trend test was run the two hypothesis were assumed: H_0 – there is no trend, H_a – there is a trend. The outcome of the test is a “decision” – either H_0 is rejected or not rejected. Failing to reject H_0 does not mean it was “proven” that there is no trend. Rather, it is a statement that the evidence available is insufficient to conclude that there is a trend. For further confirmation of the hypothesis, the closer the Tau value is to 1 (or -1) and the higher the S value, the more the trend grows.

The alpha value (significance level) adopted to test the hypothesis is that of 0.05.

Seasonal

In this chapter the results for seasonal Mann-Kendall trend tests are presented. Tables 163 to 170 show the tests’ statistics and tests’ interpretation.

Spring

Mean values

Station	Mann Kendall Test					
	S	Tau	Var (S)	p-value	Sen's slope	Test interpretation
Presa ELZ	-165	-0.0933	24579.67	0.2955	-0.0019	Accept H0
Ejido Uruapan	-268	-0.1516	24579.33	0.0886	-0.0036	Accept H0
El Álamo	-245	-0.1437	2576.67	0.1066	-0.0027	Accept H0
El Ciprés	-341	-0.1930	24575.67	0.0301	-0.0028	Reject H0
El Farito	-169	-0.0956	24580.33	0.2839	-0.0015	Accept H0
Héroes de la Independencia	-172	-0.0973	24577.33	0.2754	-0.0016	Accept H0
La Bocana	-98	-0.0554	24579.33	0.5361	-0.0010	Accept H0
Manadero	-159	-0.0899	24582.33	0.3136	-0.0018	Accept H0
Ojos Negros	-130	-0.0735	24581.33	0.4106	-0.0012	Accept H0
Olivares Mexicanos	-126	-0.0712	24581.33	0.4253	-0.0020	Accept H0
Punta Banda	-135	-0.0763	24580.33	0.3927	-0.0013	Accept H0
Real del Castillo	-55	-0.0311	24580.33	0.7305	-0.0006	Accept H0
San Carlos	-145	-0.0819	24582.33	0.3584	-0.0020	Accept H0
San Rafael	-122	-0.0690	24581.33	0.4403	-0.0016	Accept H0
Santa Isabel	-170	-0.0962	24578.67	0.2810	-0.0022	Accept H0
Santo Tomás	-110	-0.0622	24581.33	0.4869	-0.0016	Accept H0
Sierra de Juárez	30	0.0170	24579.33	0.8532	0.0004	Accept H0

Table 163 Results of the Mann-Kendall test for mean spring precipitation values

Maximum values

Station	Mann Kendall Test					
	S	Tau	Var (S)	p-value	Sen's slope	Test interpretation
Presa ELZ	-121	-0.0685	24576.33	0.4440	-0.05	Accept H0
Ejido Uruapan	-93	-0.0527	24570.33	0.5573	-0.0354	Accept H0
El Álamo	-197	-0.1120	24559.67	0.2111	-0.0729	Accept H0
El Ciprés	-65	-0.0368	24571.67	0.6831	-0.0205	Accept H0
El Farito	-90	-0.0510	24572.67	0.5702	-0.0294	Accept H0
Héroes de la Independencia	-247	-0.1400	24571.67	0.1166	-0.0853	Accept H0
La Bocana	-5	-0.0028	24573	0.9796	0	Accept H0
Maneadero	-46	-0.0260	24576.67	0.7741	-0.0176	Accept H0
Ojos Negros	-244	-0.1388	24552	0.1209	-0.0909	Accept H0
Olivares Mexicanos	-14	-0.0079	24564.67	0.9339	0	Accept H0
Punta Banda	192	0.1088	24570.67	0.2230	0.0903	Accept H0
Real del Castillo	-82	-0.0464	24579.33	0.6054	-0.0345	Accept H0
San Carlos	-130	-0.0736	24577.33	0.4106	-0.0521	Accept H0
San Rafael	-63	-0.0356	24580.33	0.6925	-0.0242	Accept H0
Santa Isabel	-254	-0.1438	24574.67	0.1065	-0.0636	Accept H0
Santo Tomás	-67	-0.0380	24562.33	0.6737	-0.0282	Accept H0
Sierra de Juárez	-101	-0.0572	24573.67	0.5235	-0.0325	Accept H0

Table 164 Results of the Mann-Kendall test for maximum spring precipitation values

Summer

Mean values

Station	Mann Kendall Test					
	S	Tau	Var (S)	p-value	Sen's slope	Test interpretation
Presa ELZ	30	0.0173	24357.33	0.8526	0	Accept H0
Ejido Uruapan	-195	-0.1123	24369.67	0.2140	-0.0006	Accept H0
El Álamo	-73	-0.0414	24565.67	0.6460	-0.0012	Accept H0
El Ciprés	-420	-0.2411	24417.33	0.0073	-0.0011	Reject H0
El Farito	76	0.0444	24221.33	0.6299	0	Accept H0
Héroes de la Independencia	17	0.0096	24582.33	0.9187	0.0003	Accept H0
La Bocana	-169	-0.0975	24363	0.2818	-0.0002	Accept H0
Maneadero	-288	-0.1648	24482.67	0.0666	-0.0009	Accept H0
Ojos Negros	-21	-0.0119	24557	0.8984	0	Accept H0
Olivares Mexicanos	-267	-0.1563	24151.67	0.0870	-0.0006	Accept H0
Punta Banda	-273	-0.1667	23147.67	0.0738	0	Accept H0
Real del Castillo	47	0.0267	24549	0.7691	0.0002	Accept H0
San Carlos	97	0.0558	24410.33	0.5389	0.0001	Accept H0
San Rafael	9	0.0051	24569.67	0.9593	0	Accept H0
Santa Isabel	-105	-0.0593	24582.33	0.5071	-0.0018	Accept H0
Santo Tomás	48	0.0298	22746	0.7553	0	Accept H0
Sierra de Juárez	36	0.0204	24579.33	0.8233	0.0002	Accept H0

Table 165 Results of the Mann-Kendall test for mean summer precipitation values

Maximum values

Station	Mann Kendall Test					
	S	Tau	Var (S)	p-value	Sen's slope	Test interpretation
Presa ELZ	27	0.0157	24341	0.8676	0	Accept H0
Ejido Uruapan	-176	-0.1018	24354.67	0.2621	-0.0175	Accept H0
El Álamo	-88	-0.0501	24547.33	0.5787	-0.0500	Accept H0
El Ciprés	-177	-0.1023	24380.33	0.2597	-0.0194	Accept H0
El Farito	47	0.0275	24213	0.7675	0	Accept H0
Héroes de la Independencia	-60	-0.0341	24560	0.7066	-0.0273	Accept H0
La Bocana	-121	-0.0700	24351.67	0.4419	-0.0075	Accept H0
Maneadero	-291	-0.1671	24463.67	0.0637	-0.0396	Accept H0
Ojos Negros	-246	-0.1407	24518.67	0.1177	-0.0447	Accept H0
Olivares Mexicanos	-247	-0.1450	24140.33	0.1134	-0.0250	Accept H0
Punta Banda	-257	-0.1573	23141.67	0.0924	0	Accept H0
Real del Castillo	-62	-0.0354	24530	0.6969	-0.0077	Accept H0
San Carlos	36	0.0208	24389.33	0.8227	0	Accept H0
San Rafael	-56	-0.0318	24557.33	0.7256	-0.0140	Accept H0
Santa Isabel	-117	-0.0663	24573.67	0.4593	-0.0500	Accept H0
Santo Tomás	62	0.0385	22740.67	0.6858	0	Accept H0
Sierra de Juárez	-46	-0.0261	24566	0.7740	-0.0094	Accept H0

Table 166 Results of the Mann-Kendall test for maximum summer precipitation values

Autumn

Mean values

Station	Mann Kendall Test					
	S	Tau	Var (S)	p-value	Sen's slope	Test interpretation
Presa ELZ	-57	-0.0322	24582.33	0.7210	-0.0013	Accept H0
Ejido Uruapan	-186	-0.1052	24578.33	0.2380	-0.0034	Accept H0
El Álamo	-54	-0.0305	24581.33	0.7353	-0.0009	Accept H0
El Ciprés	-96	-0.0543	24579.33	0.5445	-0.0013	Accept H0
El Farito	-42	-0.0237	24581.33	0.7937	-0.0006	Accept H0
Héroes de la Independencia	-51	-0.0288	24582.33	0.7498	-0.0009	Accept H0
La Bocana	-118	-0.0667	24581.33	0.4555	-0.0023	Accept H0
Maneadero	-93	-0.0526	24582.33	0.5574	-0.0014	Accept H0
Ojos Negros	-121	-0.0684	24580.33	0.4440	-0.0015	Accept H0
Olivares Mexicanos	-112	-0.0633	24581.33	0.4790	-0.0023	Accept H0
Punta Banda	-66	-0.0373	24581.33	0.6784	-0.0013	Accept H0
Real del Castillo	-39	-0.0220	24582.33	0.8085	-0.0008	Accept H0
San Carlos	-176	-0.0994	24583.33	0.2644	-0.0037	Accept H0
San Rafael	-72	-0.0407	24583.33	0.6507	-0.0013	Accept H0
Santa Isabel	-49	-0.0277	24580.33	0.7595	-0.0010	Accept H0
Santo Tomás	-82	-0.0463	24583.33	0.6054	-0.0020	Accept H0
Sierra de Juárez	16	0.0090	24581.33	0.9238	0.0006	Accept H0

Table 167 Results of the Mann-Kendall test for mean autumn precipitation values

Maximum values

Station	Mann Kendall Test					
	S	Tau	Var (S)	p-value	Sen's slope	Test interpretation
Presa ELZ	-220	-0.1245	24576.67	0.1624	-0.1052	Accept H0
Ejido Uruapan	-226	-0.1281	24570.67	0.1512	-0.1132	Accept H0
El Álamo	-94	-0.0534	24561.33	0.5529	-0.0509	Accept H0
El Ciprés	-100	-0.0567	24565.33	0.5276	-0.0350	Accept H0
El Farito	-181	-0.1025	24576.33	0.2509	-0.0581	Accept H0
Héroes de la Independencia	-90	-0.0509	24576.67	0.5702	-0.0424	Accept H0
La Bocana	-280	-0.1584	24579.33	0.0751	-0.1150	Accept H0
Maneadero	-96	-0.0543	24579.33	0.5445	-0.0436	Accept H0
Ojos Negros	-322	-0.1826	24567.33	0.0406	-0.1164	Reject H0
Olivares Mexicanos	-270	-0.1530	24573.33	0.0862	-0.1300	Accept H0
Punta Banda	-44	-0.0249	24570.67	0.7838	-0.0180	Accept H0
Real del Castillo	-92	-0.0521	24577.33	0.5616	-0.0420	Accept H0
San Carlos	-88	-0.0498	24577.33	0.5789	-0.0500	Accept H0
San Rafael	-101	-0.0571	24578.33	0.5236	-0.0454	Accept H0
Santa Isabel	-114	-0.0645	24577.33	0.4710	-0.0455	Accept H0
Santo Tomás	-115	-0.0652	24569.67	0.4671	-0.0739	Accept H0
Sierra de Juárez	-278	-0.1572	24578.67	0.0773	-0.1189	Accept H0

Table 168 Results of the Mann-Kendall test for maximum autumn precipitation values

Winter

Mean values

Station	Mann Kendall Test					
	S	Tau	Var (S)	p-value	Sen's slope	Test interpretation
Presa ELZ	142	0.0802	24583.33	0.3685	0.0075	Accept H0
Ejido Uruapan	172	0.0972	24583.33	0.2754	0.0103	Accept H0
El Álamo	175	0.0990	24580.33	0.2671	0.0084	Accept H0
El Ciprés	134	0.0757	24583.33	0.3963	0.0036	Accept H0
El Farito	159	0.0899	24580.33	0.3136	0.0048	Accept H0
Héroes de la Independencia	84	0.0475	24583.33	0.5966	0.0029	Accept H0
La Bocana	189	0.1068	24582.33	0.2305	0.0090	Accept H0
Maneadero	38	0.0215	24583.33	0.8134	0.0016	Accept H0
Ojos Negros	148	0.0836	24583.33	0.3485	0.0055	Accept H0
Olivares Mexicanos	244	0.1379	24583.33	0.1212	0.0122	Accept H0
Punta Banda	85	0.0480	24582.33	0.5921	0.0030	Accept H0
Real del Castillo	306	0.1729	24583.33	0.0517	0.0151	Accept H0
San Carlos	196	0.1107	24583.33	0.2136	0.0100	Accept H0
San Rafael	276	0.1559	24583.33	0.0794	0.0128	Accept H0
Santa Isabel	192	0.1085	24583.33	0.2232	0.0077	Accept H0
Santo Tomás	220	0.1243	24583.33	0.1625	0.0123	Accept H0
Sierra de Juárez	246	0.1390	24583.33	0.1181	0.0113	Accept H0

Table 169 Results of the Mann-Kendall test for mean winter precipitation values

Maximum values

Station	Mann Kendall Test					
	S	Tau	Var (S)	p-value	Sen's slope	Test interpretation
Presa ELZ	151	0.0855	24573.67	0.3386	0.1172	Accept H0
Ejido Uruapan	280	0.1574	24579.33	0.0751	0.3176	Accept H0
El Álamo	239	0.1353	24575.67	0.1290	0.2043	Accept H0
El Ciprés	232	0.1314	24574.67	0.1406	0.1390	Accept H0
El Farito	227	0.1285	24575	0.1494	0.1094	Accept H0
Héroes de la Independencia	-21	-0.0119	24580.33	0.8985	-0.0123	Accept H0
La Bocana	259	0.1464	24582.33	0.0999	0.2081	Accept H0
Maneadero	234	0.1324	24579.33	0.1372	0.1531	Accept H0
Ojos Negros	65	0.0368	24576.33	0.6831	0.0446	Accept H0
Olivares Mexicanos	286	0.1618	24579.33	0.0691	0.2227	Accept H0
Punta Banda	272	0.1539	24576.67	0.0839	0.2116	Accept H0
Real del Castillo	363	0.2051	24582.33	0.0210	0.2830	Reject H0
San Carlos	301	0.1702	24580.33	0.0557	0.2180	Accept H0
San Rafael	378	0.2138	24579.33	0.0162	0.2873	Reject H0
Santa Isabel	215	0.1216	24578.33	0.1722	0.1297	Accept H0
Santo Tomás	210	0.1190	24570	0.1824	0.1707	Accept H0
Sierra de Juárez	167	0.0944	24580.33	0.2897	0.1100	Accept H0

Table 170 Results of the Mann-Kendall test for maximum winter precipitation values

From what can be observed from the tables, the null hypothesis is generally accepted, that is, there is no evidence for existence or non-existence of a trend.

As for the particularities where the null hypothesis was rejected, that is, a trend was detected, the following may be noted.

In spring and summer, negative trends were detected in the mean precipitation values of the El Ciprés station (Figure 3 and Figure 4, respectively). These trends, though, are very small.

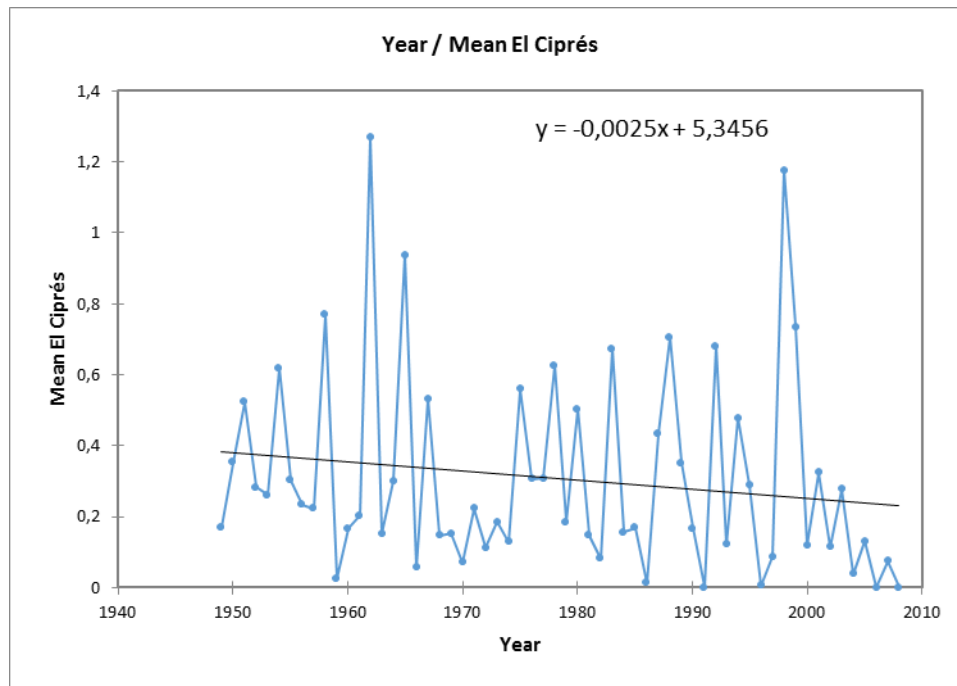


Figure 3 Linear trend line corresponding to mean spring precipitation values for El Ciprés station

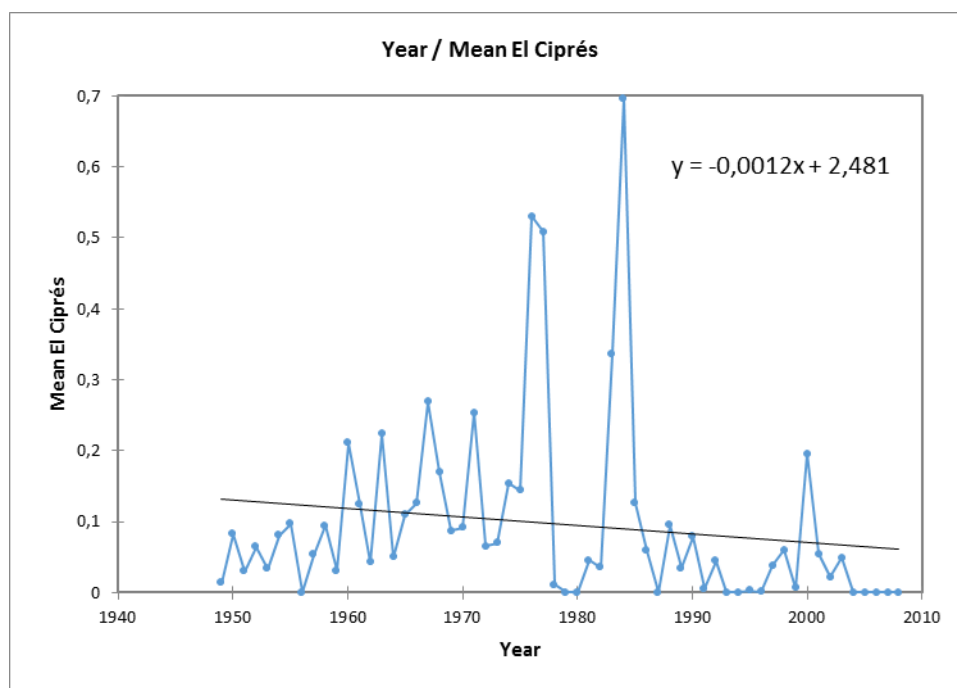


Figure 4 Linear trend line corresponding to mean summer precipitation values for El Ciprés station

In autumn, a negative trend was found in the maximum values of Ojos Negros station (Figure 5). Though small (-0.1164 according to Sen's slope), the trend is slightly more pronounced than in El Ciprés station's case for spring and summer.

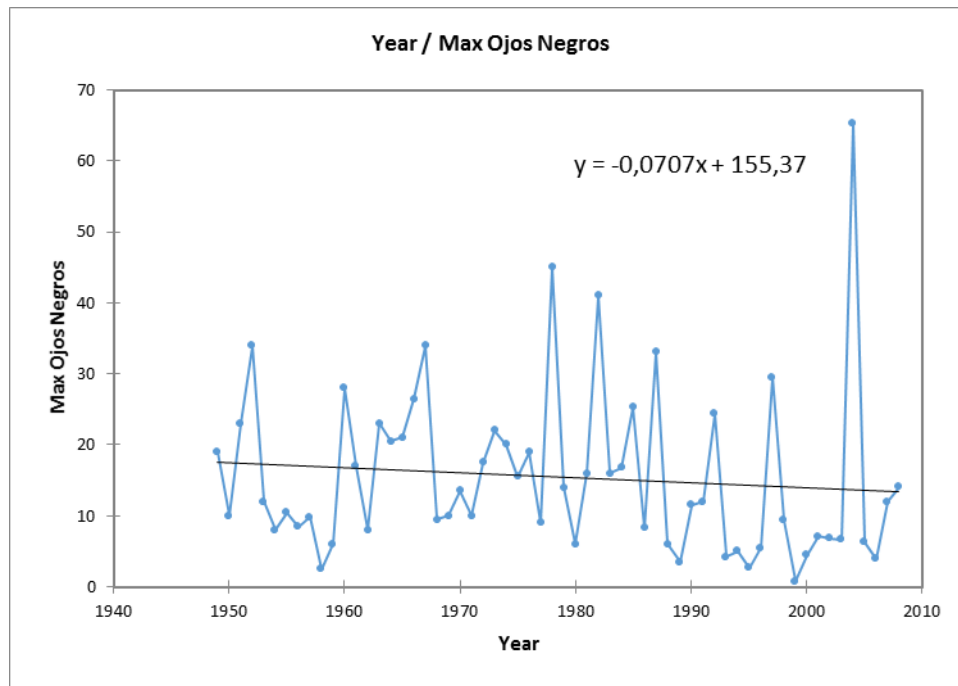


Figure 5 Linear trend line corresponding to maximum autumn precipitation values for Ojos Negros station

In case of winter, a positive trend was found in the maximum precipitation values of Real del Castillo and San Rafael stations (Figure 6 and Figure 7, respectively). In these cases, the Sen's slope is also more pronounced (0.283 and 0.2873, respectively).

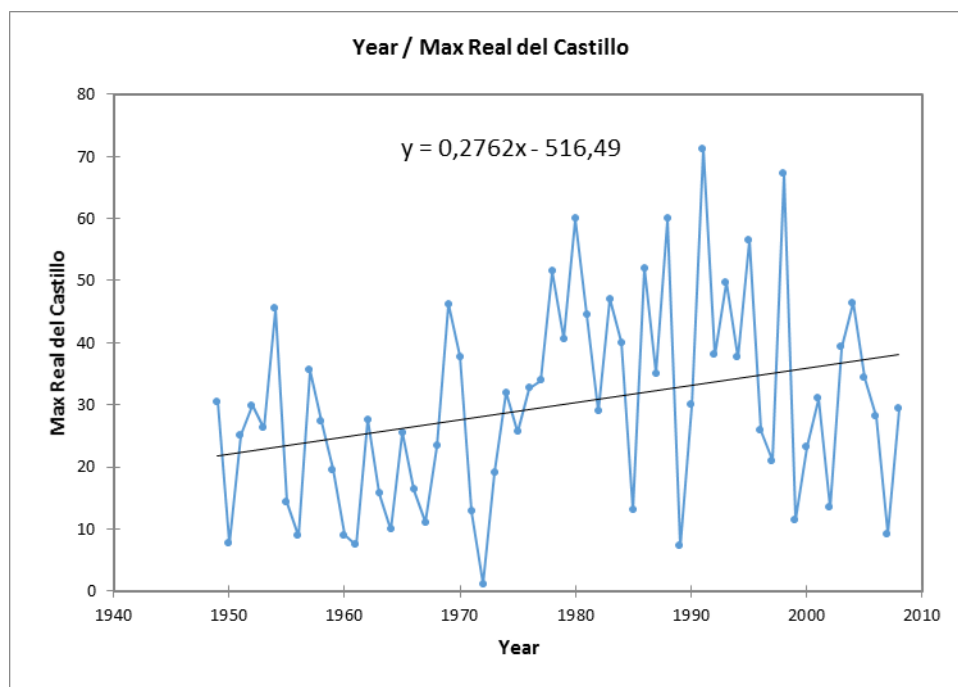


Figure 6 Linear trend line corresponding to maximum winter precipitation values for Real del Castillo station

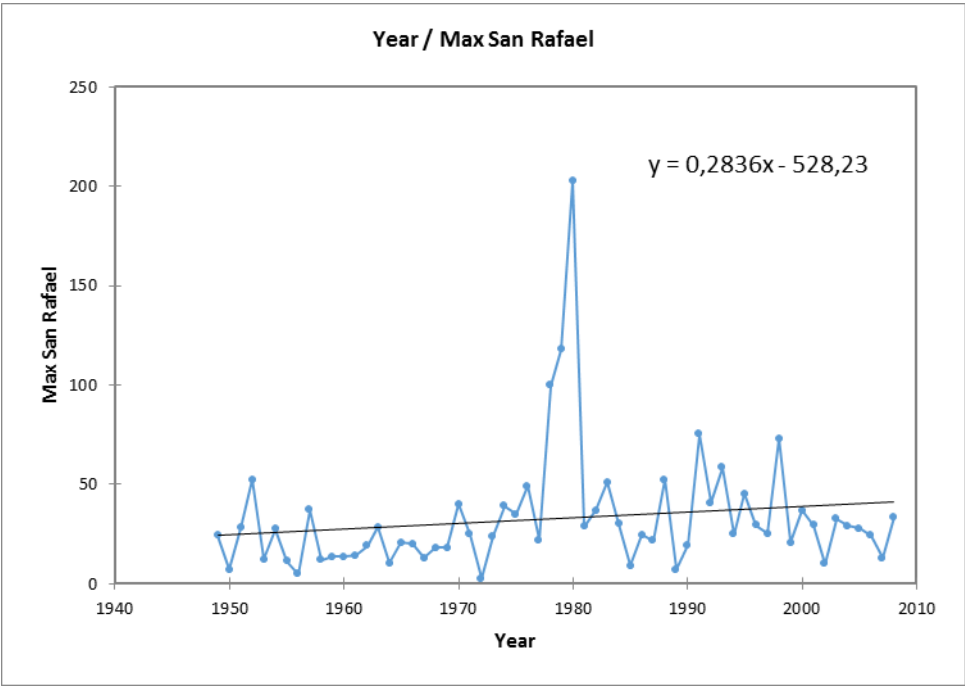


Figure 7 Linear trend line corresponding to maximum winter precipitation values for San Rafael station

Monthly

In this chapter the results for monthly Mann-Kendall trend tests are presented. Tables 171 to 194 show the tests' statistics and tests' interpretation.

January

Mean values

Station	Mann Kendall Test					
	S	Tau	Var (S)	p-value	Sen's slope	Test interpretation
Presa ELZ	-73	-0.413	24582.33	0.6461	-0.0048	Accept H0
Ejido Uruapan	-156	-0.0883	24576.67	0.3228	-0.0068	Accept H0
El Álamo	-82	-0.0465	24560.67	0.6053	-0.0024	Accept H0
El Ciprés	-149	-0.0845	24563.67	0.3450	-0.0050	Accept H0
El Farito	-83	-0.0470	24577.67	0.6009	-0.0031	Accept H0
Héroes de la Independencia	-36	-0.0204	24564.67	0.8233	-0.0007	Accept H0
La Bocana	-59	-0.0333	24582.33	0.7114	-0.0031	Accept H0
Maneadero	-135	-0.0763	24582.33	0.3927	-0.0067	Accept H0
Ojos Negros	-70	-0.0396	24578.67	0.6599	-0.0038	Accept H0
Olivares Mexicanos	-93	-0.0528	24561	0.5572	-0.0044	Accept H0
Punta Banda	-81	-0.0458	24580.33	0.6099	-0.0043	Accept H0
Real del Castillo	3	0.0017	24581.33	0.9898	0.0003	Accept H0
San Carlos	-122	-0.0634	24574.67	0.4789	-0.0057	Accept H0
San Rafael	-26	-0.0147	24581.33	0.8733	-0.0011	Accept H0
Santa Isabel	-69	-0.0390	24579.67	0.6645	-0.0027	Accept H0
Santo Tomás	-7	-0.0040	24580.33	0.9695	-0.0002	Accept H0
Sierra de Juárez	-33	-0.0186	24582.33	0.8383	-0.0014	Accept H0

Table 171 Results of the Mann-Kendall test for mean January precipitation values

Maximum values

Station	Mann Kendall Test					
	S	Tau	Var (S)	p-value	Sen's slope	Test interpretation
Presa ELZ	-77	-0.0436	24578.33	0.6278	-0.0526	Accept H0
Ejido Uruapan	-70	-0.0397	24567.33	0.6598	-0.0555	Accept H0
El Álamo	-33	-0.0188	24547.67	0.8382	-0.0023	Accept H0
El Ciprés	-124	-0.0705	24556	0.4325	-0.0500	Accept H0
El Farito	-31	-0.0175	24575.67	0.8482	-0.0114	Accept H0
Héroes de la Independencia	-14	-0.0080	24554	0.9339	0	Accept H0
La Bocana	-29	-0.0164	24578.33	0.8583	-0.0192	Accept H0
Maneadero	-38	-0.0215	24577.33	0.8134	-0.0172	Accept H0
Ojos Negros	-120	-0.0680	24570	0.4477	-0.0739	Accept H0
Olivares Mexicanos	-82	-0.0466	24558	0.6052	-0.0616	Accept H0
Punta Banda	-29	-0.0164	24576.33	0.8582	-0.0164	Accept H0
Real del Castillo	34	0.0193	24572.67	0.8333	0.0174	Accept H0
San Carlos	-84	-0.0476	24572.67	0.5965	-0.0515	Accept H0
San Rafael	-25	-0.0142	24575.67	0.8783	-0.0104	Accept H0
Santa Isabel	-52	-0.0294	24579.33	0.7450	-0.0220	Accept H0
Santo Tomás	4	0.0023	24572.67	0.9847	0	Accept H0
Sierra de Juárez	-49	0.0277	24580.33	0.7595	-0.0307	Accept H0

Table 172 Results of the Mann-Kendall test for maximum January precipitation values

February

Mean values

Station	Mann Kendall Test					
	S	Tau	Var (S)	p-value	Sen's slope	Test interpretation
Presa ELZ	299	0.1691	24580.33	0.0573	0.0173	Accept H0
Ejido Uruapan	382	0.2161	24578.67	0.0151	0.0261	Reject H0
El Álamo	381	0.2167	24537	0.0153	0.0234	Reject H0
El Ciprés	253	0.1431	24577.67	0.1080	0.0115	Accept H0
El Farito	292	0.1651	24581.33	0.0634	0.0110	Accept H0
Héroes de la Independencia	322	0.1826	24562.67	0.0405	0.0129	Reject H0
La Bocana	323	0.1826	24580.33	0.0400	0.0219	Reject H0
Maneadero	205	0.1159	24582.33	0.1932	0.0081	Accept H0
Ojos Negros	330	0.1865	24581.33	0.0359	0.0155	Reject H0
Olivares Mexicanos	387	0.2188	24580.33	0.0138	0.0275	Reject H0
Punta Banda	137	0.0777	24563.67	0.3855	0.0061	Accept H0
Real del Castillo	385	0.2176	24581.33	0.0143	0.0240	Reject H0
San Carlos	270	0.1527	24578.67	0.0862	0.0181	Accept H0
San Rafael	389	0.2200	24578.67	0.0133	0.0238	Reject H0
Santa Isabel	417	0.2359	24578.33	0.0080	0.0237	Reject H0
Santo Tomás	331	0.1874	24575.67	0.0353	0.0219	Reject H0
Sierra de Juárez	374	0.2114	24581.33	0.0174	0.0237	Reject H0

Table 173 Results of the Mann-Kendall test for mean February precipitation values

Maximum values

Station	Mann Kendall Test					
	S	Tau	Var (S)	p-value	Sen's slope	Test interpretation
Presa ELZ	293	0.1659	24576.33	0.0625	0.1791	Accept H0
Ejido Uruapan	383	0.2168	24575	0.0148	0.3250	Reject H0
El Álamo	363	0.2076	24507.67	0.0208	0.2560	Reject H0
El Ciprés	327	0.1851	24575.67	0.0376	0.1667	Reject H0
El Farito	259	0.1466	24576.33	0.0998	0.1188	Accept H0
Héroes de la Independencia	233	0.1321	24563.67	0.1388	0.1289	Accept H0
La Bocana	364	0.2059	24579.33	0.0206	0.2510	Reject H0
Maneadero	188	0.1063	24579.33	0.2330	0.1000	Accept H0
Ojos Negros	168	0.0953	24568	0.2867	0.0851	Accept H0
Olivares Mexicanos	392	0.2224	24568	0.0126	0.2754	Reject H0
Punta Banda	154	0.0874	24562.67	0.3289	0.1000	Accept H0
Real del Castillo	329	0.1861	24578.33	0.0364	0.1989	Reject H0
San Carlos	251	0.1420	24577.67	0.1108	0.1880	Accept H0
San Rafael	416	0.2356	24574.67	0.0081	0.2640	Reject H0
Santa Isabel	347	0.1964	24575.67	0.0273	0.1725	Reject H0
Santo Tomás	294	0.1667	24570	0.0616	0.2500	Accept H0
Sierra de Juárez	294	0.1665	24574.67	0.0616	0.1527	Accept H0

Table 174 Results of the Mann-Kendall test for maximum February precipitation values

March

Mean values

Station	Mann Kendall Test					
	S	Tau	Var (S)	p-value	Sen's slope	Test interpretation
Presa ELZ	118	0.0668	24572.67	0.4554	0.0051	Accept H0
Ejido Uruapan	26	0.0148	24538	0.8732	0.0001	Accept H0
El Álamo	117	0.0665	24537	0.4590	0.0035	Accept H0
El Ciprés	11	0.0062	24563.67	0.9491	0	Accept H0
El Farito	108	0.0613	24562.67	0.4948	0.0028	Accept H0
Héroes de la Independencia	195	0.1108	24551	0.2157	0.0069	Accept H0
La Bocana	151	0.0855	24573.37	0.3386	0.0060	Accept H0
Maneadero	53	0.0300	24575.67	0.740	0.0024	Accept H0
Ojos Negros	100	0.0567	24564.67	0.5276	0.0040	Accept H0
Olivares Mexicanos	123	0.0697	24565.67	0.4363	0.0062	Accept H0
Punta Banda	53	0.0301	24563.67	0.7401	0.0020	Accept H0
Real del Castillo	206	0.1166	24574.67	0.1910	0.0087	Accept H0
San Carlos	79	0.0447	24579.67	0.6188	0.0050	Accept H0
San Rafael	181	0.1024	24575	0.2509	0.0075	Accept H0
Santa Isabel	104	0.0588	24581.33	0.5112	0.0043	Accept H0
Santo Tomás	98	0.0556	24554	0.5359	0.0050	Accept H0
Sierra de Juárez	119	0.0674	24575.67	0.4516	0.0056	Accept H0

Table 175 Results of the Mann-Kendall test for mean March precipitation values

Maximum values

Station	Mann Kendall Test					
	S	Tau	Var (S)	p-value	Sen's slope	Test interpretation
Presa ELZ	157	0.0890	24569.67	0.3196	0.0943	Accept H0
Ejido Uruapan	178	0.1013	24536	0.2585	0.1156	Accept H0
El Álamo	276	0.1579	24509.33	0.0790	0.1742	Accept H0
El Ciprés	223	0.1265	24561.67	0.1566	0.1000	Accept H0
El Farito	136	0.0771	24564.67	0.3890	0.0701	Accept H0
Héroes de la Independencia	216	0.1228	24547.33	0.1700	0.1000	Accept H0
La Bocana	186	0.1053	24572.67	0.2379	0.0932	Accept H0
Maneadero	201	0.1138	24573	0.2020	0.1128	Accept H0
Ojos Negros	56	0.0318	24554	0.7256	0.0208	Accept H0
Olivares Mexicanos	227	0.1293	24541	0.1494	0.1500	Accept H0
Punta Banda	192	0.1090	24560.67	0.2229	0.1479	Accept H0
Real del Castillo	208	0.1179	24568	0.1866	0.1244	Accept H0
San Carlos	258	0.1461	24574.67	0.1011	0.2078	Accept H0
San Rafael	278	0.1574	24574.67	0.0772	0.1346	Accept H0
Santa Isabel	246	0.1395	24570.67	0.1181	0.1186	Accept H0
Santo Tomás	110	0.0627	24534	0.4865	0.0541	Accept H0
Sierra de Juárez	111	0.0629	24571	0.4828	0.0590	Accept H0

Table 176 Results of the Mann-Kendall test for maximum March precipitation values

April

Mean values

Station	Mann Kendall Test					
	S	Tau	Var (S)	p-value	Sen's slope	Test interpretation
Presa ELZ	-76	-0.0432	24538	0.6321	-0.0013	Accept H0
Ejido Uruapan	-100	-0.0573	24452.67	0.5267	-0.0011	Accept H0
El Álamo	-41	-0.0239	24231	0.7972	0	Accept H0
El Ciprés	-189	-0.1081	24483	0.2296	-0.0022	Accept H0
El Farito	-126	-0.0718	24514	0.4247	-0.0013	Accept H0
Héroes de la Independencia	-50	-0.0290	24244.67	0.7530	0	Accept H0
La Bocana	-23	-0.0131	24517	0.8883	0	Accept H0
Maneadero	-64	-0.0363	24560	0.6877	-0.0010	Accept H0
Ojos Negros	-24	-0.0137	24526.67	0.8832	0	Accept H0
Olivares Mexicanos	18	0.0103	24487.33	0.9135	0	Accept H0
Punta Banda	-42	-0.0241	24453.33	0.7932	0	Accept H0
Real del Castillo	-27	-0.0154	24537	0.8682	-0.0003	Accept H0
San Carlos	-150	-0.0853	24536	0.3415	-0.0029	Accept H0
San Rafael	-57	-0.0326	24456.33	0.7203	-0.0002	Accept H0
Santa Isabel	-26	-0.0148	24560	0.8733	-0.0003	Accept H0
Santo Tomás	-18	-0.0104	24410.67	0.9134	0	Accept H0
Sierra de Juárez	118	0.0670	24552	0.4552	0.0025	Accept H0

Table 177 Results of the Mann-Kendall test for mean April precipitation values

Maximum values

Station	Mann Kendall Test					
	S	Tau	Var (S)	p-value	Sen's slope	Test interpretation
Presa ELZ	-97	-0.0553	24530.33	0.5399	-0.0272	Accept H0
Ejido Uruapan	-18	-0.0103	24455.33	0.9134	0	Accept H0
El Álamo	-51	-0.0297	24233	0.7481	0	Accept H0
El Ciprés	-110	-0.0629	24483.33	0.4860	-0.0182	Accept H0
El Farito	-113	-0.0645	24509	0.4744	-0.0218	Accept H0
Héroes de la Independencia	-104	-0.0604	24244	0.5083	-0.0029	Accept H0
La Bocana	-15	-0.0086	24508.33	0.9287	0	Accept H0
Maneadero	-28	-0.0159	24554	0.8632	-0.0050	Accept H0
Ojos Negros	-141	-0.0806	24515	0.3712	-0.0357	Accept H0
Olivares Mexicanos	56	0.0321	24476.67	0.7252	0.0093	Accept H0
Punta Banda	101	0.0580	24443.67	0.5224	0.0256	Accept H0
Real del Castillo	-70	-0.0399	24531.33	0.6595	-0.0148	Accept H0
San Carlos	-46	-0.0262	24530	0.7739	-0.0115	Accept H0
San Rafael	-30	-0.0172	24455.33	0.8529	0	Accept H0
Santa Isabel	-69	-0.0393	24548.33	0.6643	-0.0140	Accept H0
Santo Tomás	-25	-0.0144	24395.67	0.8779	0	Accept H0
Sierra de Juárez	9	0.0051	24545	0.9593	0	Accept H0

Table 178 Results of the Mann-Kendall test for maximum April precipitation values

May

Mean values

Station	Mann Kendall Test					
	S	Tau	Var (S)	p-value	Sen's Slope	Test interpretation
Presa ELZ	16	0.0095	23874.67	0.9227	0	Accept H0
Ejido Uruapan	-171	0.1062	22745	0.2597	0	Accept H0
El Álamo	-17	-0.0124	18254.33	0.9057	0	Accept H0
El Ciprés	-340	-0.2112	22744	0.0246	-0.003	Reject H0
El Farito	27	0.0162	23618.33	0.8657	0	Accept H0
Héroes de la Independencia	89	0.0594	20775.67	0.5415	0	Accept H0
La Bocana	15	0.0091	23317	0.9269	0	Accept H0
Maneadero	-11	-0.0065	24080.33	0.9486	0	Accept H0
Ojos Negros	145	0.0888	23139	0.3438	0	Accept H0
Olivares Mexicanos	13	0.0079	23317	0.9374	0	Accept H0
Punta Banda	-327	-0.2089	22014.33	0.0280	0	Reject H0
Real del Castillo	65	0.0387	23757.67	0.6780	0	Accept H0
San Carlos	-47	-0.0272	24356.33	0.7682	0	Accept H0
San Rafael	-16	-0.0098	23144.67	0.9215	0	Accept H0
Santa Isabel	12	0.0069	24508	0.9440	0	Accept H0
Santo Tomás	-6	-0.0038	22012.67	0.9731	0	Accept H0
Sierra de Juárez	208	0.1208	24246.67	0.1837	0.0009	Accept H0

Table 179 Results of the Mann-Kendall test for mean May precipitation values

Maximum values

Station	Mann Kendall Test					
	S	Tau	Var (S)	p-value	Sen's slope	Test interpretation
Presa ELZ	13	0.0077	23865.67	0.9381	0	Accept H0
Ejido Uruapan	-150	0.0932	22744	0.3232	0	Accept H0
El Álamo	-18	-0.0131	18250.67	0.8999	0	Accept H0
El Ciprés	-328	-0.2038	22743.33	0.0301	-0.0062	Reject H0
El Farito	54	0.0324	23624.67	0.7302	0	Accept H0
Héroes de la Independencia	81	0.0541	20770.33	0.5788	0	Accept H0
La Bocana	20	0.0122	23315.33	0.9010	0	Accept H0
Maneadero	-30	-0.0177	24055.33	0.8517	0	Accept H0
Ojos Negros	132	0.0810	23128.67	0.3890	0	Accept H0
Olivares Mexicanos	20	0.0121	23318	0.9010	0	Accept H0
Punta Banda	-317	-0.2026	22011	0.0332	0	Reject H0
Real del Castillo	61	0.0364	23751.67	0.6970	0	Accept H0
San Carlos	-7	-0.0041	24341.67	0.9693	0	Accept H0
San Rafael	-8	-0.0049	23140	0.9633	0	Accept H0
Santa Isabel	104	0.0606	24337.33	0.5091	0.0010	Accept H0
Santo Tomás	-34	-0.0218	22000	0.8239	0	Accept H0
Sierra de Juárez	64	0.0374	24216	0.6856	0	Accept H0

Table 180 Results of the Mann-Kendall test for maximum May precipitation values

June

Mean values

Station	Mann Kendall Test					
	S	Tau	Var (S)	p-value	Sen's slope	Test interpretation
Presa ELZ	128	0.0892	19612.67	0.3645	0	Accept H0
Ejido Uruapan	46	0.0373	15443.33	0.7173	0	Accept H0
El Álamo	157	0.1540	11115	0.1390	0	Accept H0
El Ciprés	-4	-0.0028	19612.67	0.9829	0	Accept H0
El Farito	139	0.0981	19187.67	0.3191	0	Accept H0
Héroes de la Independencia	108	0.0922	14128.67	0.3680	0	Accept H0
La Bocana	219	0.1597	18252.33	0.1066	0	Accept H0
Maneadero	216	0.1464	20402.67	0.1323	0	Accept H0
Ojos Negros	213	0.1814	14132.33	0.0745	0	Accept H0
Olivares Mexicanos	136	0.1029	17212	0.3035	0	Accept H0
Punta Banda	-35	-0.0298	14130.33	0.7749	0	Accept H0
Real del Castillo	98	0.0757	16652.67	0.4522	0	Accept H0
San Carlos	87	0.0645	17747.67	0.5186	0	Accept H0
San Rafael	260	0.2011	16650	0.0447	0	Reject H0
Santa Isabel	60	0.0358	23847.33	0.7024	0	Accept H0
Santo Tomás	118	0.1337	8519.33	0.2049	0	Accept H0
Sierra de Juárez	296	0.1915	21720.67	0.0453	0	Reject H0

Table 181 Results of the Mann-Kendall test for mean June precipitation values

Maximum values

Station	Mann Kendall Test					
	S	Tau	Var (S)	p-value	Sen's slope	Test interpretation
Presa ELZ	113	0.0788	19607.67	0.4238	0	Accept H0
Ejido Uruapan	55	0.0446	15442.33	0.6639	0	Accept H0
El Álamo	157	0.1540	11115	0.1390	0	Accept H0
El Ciprés	-44	-0.0308	19599.33	0.7587	0	Accept H0
El Farito	112	0.0791	19186.67	0.4229	0	Accept H0
Héroes de la Independencia	104	0.0887	14127.67	0.3862	0	Accept H0
La Bocana	20	0.1515	18237.67	0.1272	0	Accept H0
Maneadero	190	0.1293	20386	0.1856	0	Accept H0
Ojos Negros	214	0.1824	14131.33	0.0732	0	Accept H0
Olivares Mexicanos	134	0.1016	17207.33	0.3106	0	Accept H0
Punta Banda	-35	-0.0299	14127.67	0.7748	0	Accept H0
Real del Castillo	86	0.0665	16650	0.5101	0	Accept H0
San Carlos	80	0.0595	17742	0.5531	0	Accept H0
San Rafael	251	0.1947	16642.33	0.0526	0	Accept H0
Santa Isabel	213	0.1324	23378.33	0.1656	0	Accept H0
Santo Tomás	118	0.1337	8519.33	0.2049	0	Accept H0
Sierra de Juárez	295	0.1943	21569.67	0.0453	0	Reject H0

Table 182 Results of the Mann-Kendall test for maximum June precipitation values

July

Mean values

Station	Mann Kendall Test					
	S	Tau	Var (S)	p-value	Sen's slope	Test interpretation
Presa ELZ	-32	-0.0223	19608.67	0.8248	0	Accept H0
Ejido Uruapan	-203	-0.1337	21119.67	0.1645	0	Accept H0
El Álamo	-116	-0.0740	22019.33	0.4383	0	Accept H0
El Ciprés	-430	-0.2671	22743.33	0.0044	-0.0006	Reject H0
El Farito	-41	-0.0300	18238.33	0.7671	0	Accept H0
Héroes de la Independencia	-52	-0.0306	23992	0.7420	0	Accept H0
La Bocana	-155	-0.1047	20415	0.2811	0	Accept H0
Maneadero	-334	-0.2075	22743.33	0.0272	-0.0003	Reject H0
Ojos Negros	-71	-0.0443	22727	0.6424	0	Accept H0
Olivares Mexicanos	-100	-0.0746	17721.33	0.4571	0	Accept H0
Punta Banda	-379	-0.2870	17211	0.0040	0	Reject H0
Real del Castillo	-132	-0.0803	23313.33	0.3909	0	Accept H0
San Carlos	-150	-0.0969	21729.33	0.3121	0	Accept H0
San Rafael	1	0.0006	22950.33	1	0	Accept H0
Santa Isabel	-104	-0.0590	24562	0.5110	-0.0017	Accept H0
Santo Tomás	-84	-0.0678	15452	0.5045	0	Accept H0
Sierra de Juárez	35	0.0202	24365.67	0.8276	0	Accept H0

Table 183 Results of the Mann-Kendall test for mean July precipitation values

Maximum values

Station	Mann Kendall Test					
	S	Tau	Var (S)	p-value	Sen's slope	Test interpretation
Presa ELZ	-45	-0.0314	19607.67	0.7534	0	Accept H0
Ejido Uruapan	-212	-0.1397	21118	0.1465	0	Accept H0
El Álamo	-101	-0.0644	22018.33	0.5004	0	Accept H0
El Ciprés	-387	-0.2418	22717	0.0104	-0.0095	Reject H0
El Farito	-42	-0.0307	18239.33	0.7614	0	Accept H0
Héroes de la Independencia	-63	-0.0371	23984.33	0.6889	0	Accept H0
La Bocana	-156	-0.1056	20406.67	0.2779	0	Accept H0
Maneadero	-370	-0.2303	22736.67	0.0144	-0.0094	Reject H0
Ojos Negros	-93	-0.0580	22727	0.5417	0	Accept H0
Olivares Mexicanos	-98	-0.0731	17730	0.4663	0	Accept H0
Punta Banda	-387	-0.2931	17211	0.0033	0	Reject H0
Real del Castillo	-145	-0.0882	23312.33	0.3456	0	Accept H0
San Carlos	-164	-0.1060	21727.33	0.2688	0	Accept H0
San Rafael	-28	-0.0173	22948.67	0.8585	0	Accept H0
Santa Isabel	-192	-0.1095	24538	0.2227	-0.0167	Accept H0
Santo Tomás	-88	-0.0711	15452	0.4840	0	Accept H0
Sierra de Juárez	-40	-0.0232	24346	0.8026	0	Accept H0

Table 184 Results of the Mann-Kendall test for maximum July precipitation values

August

Mean values

Station	Mann Kendall Test					
	S	Tau	Var (S)	p-value	Sen's slope	Test interpretation
Presa ELZ	107	0.0733	20026.33	0.4538	0	Accept H0
Ejido Uruapan	-176	-0.1159	21118.67	0.2285	0	Accept H0
El Álamo	-122	-0.0714	24090	0.4356	-0.0005	Accept H0
El Ciprés	-405	-0.2459	23319.67	0.0082	-0.0007	Reject H0
El Farito	117	0.0813	19618.33	0.4076	0	Accept H0
Héroes de la Independencia	-20	-0.0115	24415.33	0.9032	0	Accept H0
La Bocana	-80	-0.0533	20778.67	0.5837	0	Accept H0
Maneadero	-212	-0.1367	21734.67	0.1524	0	Accept H0
Ojos Negros	125	0.0770	22950.33	0.4131	0	Accept H0
Olivares Mexicanos	-111	-0.0783	19187.66	0.4271	0	Accept H0
Punta Banda	-182	-0.1379	17210	0.1677	0	Accept H0
Real del Castillo	109	0.0653	23627.67	0.4823	0	Accept H0
San Carlos	180	0.1160	21736.67	0.2247	0	Accept H0
San Rafael	82	0.0483	23987.33	0.6010	0	Accept H0
Santa Isabel	-25	-0.0142	24573.67	0.8783	-0.0006	Accept H0
Santo Tomás	167	0.1289	16655.67	0.1984	0	Accept H0
Sierra de Juárez	57	0.0324	24549	0.7208	0.0005	Accept H0

Table 185 Results of the Mann-Kendall test for mean August precipitation values

Maximum values

Station	Mann Kendall Test					
	S	Tau	Var (S)	p-value	Sen's slope	Test interpretation
Presa ELZ	101	0.0694	20019	0.4797	0	Accept H0
Ejido Uruapan	-201	-0.1327	21113.67	0.1687	0	Accept H0
El Álamo	-173	-0.1014	24083	0.2677	-0.0261	Accept H0
El Ciprés	-366	-0.2226	23314	0.0168	-0.0125	Reject H0
El Farito	104	0.0724	19613.33	0.4621	0	Accept H0
Héroes de la Independencia	-59	-0.0339	24409.67	0.7105	0	Accept H0
La Bocana	-100	-0.0669	20765.33	0.4921	0	Accept H0
Maneadero	-234	-0.1516	21714	0.1138	0	Accept H0
Ojos Negros	81	0.0501	22925.67	0.5973	0	Accept H0
Olivares Mexicanos	-109	-0.0770	19183	0.4355	0	Accept H0
Punta Banda	-179	-0.1356	17211	0.1748	0	Accept H0
Real del Castillo	69	0.0415	23606.33	0.6581	0	Accept H0
San Carlos	168	0.1084	21732	0.2573	0	Accept H0
San Rafael	15	0.0088	23989	0.9280	0	Accept H0
Santa Isabel	-123	-0.0699	24559.67	0.4363	-0.0333	Accept H0
Santo Tomás	162	0.1251	16654.67	0.2122	0	Accept H0
Sierra de Juárez	-9	-0.0051	24533.67	0.9593	0	Accept H0

Table 186 Results of the Mann-Kendall test for maximum August precipitation values

September

Mean values

Station	Mann Kendall Test					
	S	Tau	Var (S)	p-value	Sen's slope	Test interpretation
Presa ELZ	142	0.0916	21734.67	0.3389	0	Accept H0
Ejido Uruapan	-120	-0.0773	21739.33	0.4196	0	Accept H0
El Álamo	38	0.0245	21737.33	0.8018	0	Accept H0
El Ciprés	-244	-0.1545	22272	0.1035	0	Accept H0
El Farito	160	0.1044	21434	0.2775	0	Accept H0
Héroes de la Independencia	54	0.0332	22956	0.7265	0	Accept H0
La Bocana	-125	-0.0805	21738.33	0.4003	0	Accept H0
Maneadero	-3	-0.0019	22740.33	0.9894	0	Accept H0
Ojos Negros	195	0.1243	22020.33	0.1911	0	Accept H0
Olivares Mexicanos	-186	-0.1240	20778.67	0.1994	0	Accept H0
Punta Banda	-67	-0.0481	18729.67	0.6296	0	Accept H0
Real del Castillo	96	0.0592	22951.33	0.5306	0	Accept H0
San Carlos	53	0.0332	22521	0.7290	0	Accept H0
San Rafael	6	0.0037	22956	0.9739	0	Accept H0
Santa Isabel	25	0.0143	24490.33	0.8781	0	Accept H0
Santo Tomás	134	0.1013	17214.67	0.3107	0	Accept H0
Sierra de Juárez	86	0.0498	24308.67	0.5856	0.0001	Accept H0

Table 187 Results of the Mann-Kendall test for mean September precipitation values

Maximum values

Station	Mann Kendall Test					
	S	Tau	Var (S)	p-value	Sen's slope	Test interpretation
Presa ELZ	146	0.0944	21723.33	0.3252	0	Accept H0
Ejido Uruapan	-146	-0.0941	21737.33	0.3254	0	Accept H0
El Álamo	59	0.0380	21737.67	0.6940	0	Accept H0
El Ciprés	-207	-0.1312	22267	0.1674	0	Accept H0
El Farito	167	0.1091	21427.67	0.2568	0	Accept H0
Héroes de la Independencia	58	0.0357	22951.33	0.7067	0	Accept H0
La Bocana	-114	-0.0736	21732.67	0.4434	0	Accept H0
Maneadero	-50	-0.0312	22730	0.7452	0	Accept H0
Ojos Negros	167	0.1067	22013.67	0.2632	0	Accept H0
Olivares Mexicanos	-186	-0.1242	20774	0.1993	0	Accept H0
Punta Banda	-73	-0.0524	18729	0.5988	0	Accept H0
Real del Castillo	97	0.0598	2947.67	0.5263	0	Accept H0
San Carlos	34	0.0214	22510.67	0.8259	0	Accept H0
San Rafael	1	0.0006	22955	1	0	Accept H0
Santa Isabel	11	0.0063	24473	0.9490	0	Accept H0
Santo Tomás	133	0.1007	17211.67	0.3143	0	Accept H0
Sierra de Juárez	8	0.0047	24281.33	0.9642	0	Accept H0

Table 188 Results of the Mann-Kendall test for maximum September precipitation values

Station	Mann Kendall Test					
	S	Tau	Var (S)	p-value	Sen's slope	Test interpretation
Presa ELZ	95	0.0562	23884.33	0.5430	0	Accept H0
Ejido Uruapan	-61	-0.0373	23143	0.6933	0	Accept H0
El Álamo	165	0.1028	22731	0.2767	0	Accept H0
El Ciprés	-24	-0.0140	24160.67	0.8824	0	Accept H0
El Farito	120	0.0714	23763.33	0.4401	0	Accept H0
Héroes de la Independencia	244	0.1491	23146.67	0.1102	0	Accept H0
La Bocana	55	0.0333	23323.67	0.7236	0	Accept H0
Maneadero	26	0.0151	24246	0.8724	0	Accept H0
Ojos Negros	60	0.0356	23872.67	0.7026	0	Accept H0
Olivares Mexicanos	70	0.0415	23878.67	0.6552	0	Accept H0
Punta Banda	-84	-0.0536	22019.33	0.5759	0	Accept H0
Real del Castillo	73	0.0424	24243	0.6438	0	Accept H0
San Carlos	7	0.0041	24082.33	0.9692	0	Accept H0
San Rafael	118	0.0681	24362	0.4535	0.0004	Accept H0
Santa Isabel	115	0.0657	24505.67	0.4665	0.0010	Accept H0
Santo Tomás	104	0.0651	22522	0.4925	0	Accept H0
Sierra de Juárez	41	0.0235	24454.33	0.7981	0	Accept H0

Table 189 Results of the Mann-Kendall test for mean October precipitation values

Maximum values

Station	Mann Kendall Test					
	S	Tau	Var (S)	p-value	Sen's slope	Test interpretation
Presa ELZ	105	0.0623	23875.67	0.5009	0	Accept H0
Ejido Uruapan	-52	-0.0318	23137.33	0.7374	0	Accept H0
El Álamo	176	0.1100	22717.33	0.2456	0	Accept H0
El Ciprés	-21	-0.0123	24151.67	0.8976	0	Accept H0
El Farito	106	0.0631	23760.67	0.4958	0	Accept H0
Héroes de la Independencia	197	0.1204	23145.67	0.1976	0	Accept H0
La Bocana	63	0.0382	23319.67	0.6847	0	Accept H0
Maneadero	29	0.0169	24238.33	0.8573	0	Accept H0
Ojos Negros	32	0.0190	23871.33	0.8410	0	Accept H0
Olivares Mexicanos	69	0.0409	23873	0.6599	0	Accept H0
Punta Banda	-75	-0.0479	22013.67	0.6180	0	Accept H0
Real del Castillo	47	0.0274	24232.33	0.7676	0	Accept H0
San Carlos	-12	-0.0070	24081.33	0.9435	0	Accept H0
San Rafael	101	0.058	24361.67	0.5217	0.0054	Accept H0
Santa Isabel	172	0.0987	24484.67	0.2745	0.0162	Accept H0
Santo Tomás	87	0.0546	22517	0.5666	0	Accept H0
Sierra de Juárez	-4	-0.0023	24433.33	0.9847	0	Accept H0

Table 190 Results of the Mann-Kendall test for maximum October precipitation values

Station	Mann Kendall Test					
	S	Tau	Var (S)	p-value	Sen's slope	Test interpretation
Presa ELZ	-154	-0.0878	24516	0.3285	-0.0036	Accept H0
Ejido Uruapan	-195	-0.1115	24486.33	0.2151	-0.0049	Accept H0
El Álamo	-135	-0.0773	24479.67	0.3917	-0.0028	Accept H0
El Ciprés	-95	-0.0540	24537	0.5484	-0.0013	Accept H0
El Farito	-134	-0.0767	24457.33	0.3951	-0.0017	Accept H0
Héroes de la Independencia	-158	-0.0902	24508.67	0.3159	-0.0023	Accept H0
La Bocana	-140	-0.0796	24534.33	0.3749	-0.0033	Accept H0
Maneadero	-109	-0.0617	24571.67	0.4908	-0.0022	Accept H0
Ojos Negros	-57	-0.0328	24412.33	0.7200	0	Accept H0
Olivares Mexicanos	-130	-0.0743	24485.33	0.4097	-0.0035	Accept H0
Punta Banda	-158	-0.0900	24516	0.3160	-0.0035	Accept H0
Real del Castillo	-47	-0.0267	24553	0.7691	-0.0008	Accept H0
San Carlos	-185	-0.1048	24565.67	0.2404	-0.0056	Accept H0
San Rafael	-161	-0.0920	24488.33	0.3066	-0.0035	Accept H0
Santa Isabel	-126	-0.0713	24579.33	0.4253	-0.0031	Accept H0
Santo Tomás	-99	-0.0563	24537	0.5316	-0.0018	Accept H0
Sierra de Juárez	-75	-0.0425	24563.67	0.6368	-0.0019	Accept H0

Table 191 Results of the Mann-Kendall test for mean November precipitation values

Maximum values

Station	Mann Kendall Test					
	S	Tau	Var (S)	p-value	Sen's slope	Test interpretation
Presa ELZ	-227	-0.1295	24510.33	0.1489	-0.1060	Accept H0
Ejido Uruapan	-257	-0.1472	24477.67	0.1018	-0.1340	Accept H0
El Álamo	-185	-0.1062	24466.33	0.2395	-0.0667	Accept H0
El Ciprés	-121	-0.0690	24528.33	0.4436	-0.0236	Accept H0
El Farito	-214	-0.1226	24453.33	0.1732	-0.0618	Accept H0
Héroes de la Independencia	-113	-0.0646	24496.33	0.4742	-0.0362	Accept H0
La Bocana	-243	-0.1383	24535	0.1224	-0.1000	Accept H0
Maneadero	-117	-0.0663	24569	0.4593	-0.0426	Accept H0
Ojos Negros	-167	-0.0961	24409.67	0.2880	-0.0657	Accept H0
Olivares Mexicanos	-237	-0.1356	24481.67	0.1315	-0.1323	Accept H0
Punta Banda	-176	-0.1003	24514	0.2637	-0.0659	Accept H0
Real del Castillo	-115	-0.0654	24546.33	0.4668	-0.0426	Accept H0
San Carlos	-153	-0.0869	24558.33	0.3321	-0.0714	Accept H0
San Rafael	-176	-0.1005	24489.33	0.2634	-0.0694	Accept H0
Santa Isabel	-163	-0.0926	24553	0.3012	-0.0521	Accept H0
Santo Tomás	-163	-0.0929	24528.33	0.3010	-0.0650	Accept H0
Sierra de Juárez	-215	-0.1220	24561.67	0.1721	-0.0766	Accept H0

Table 192 Results of the Mann-Kendall test for maximum November precipitation values

December

Mean values

Station	Mann Kendall Test					
	S	Tau	Var (S)	p-value	Sen's slope	Test interpretation
Presa ELZ	-25	-0.0146	23383.67	0.8753	-0.0009	Accept H0
Ejido Uruapan	-115	-0.0679	23352.33	0.4557	-0.0038	Accept H0
El Álamo	6	0.0036	23256.67	0.9738	0	Accept H0
El Ciprés	-105	-0.0615	23371	0.4963	-0.0019	Accept H0
El Farito	-33	-0.0193	23381.67	0.8342	-0.0006	Accept H0
Héroes de la Independencia	32	0.0189	23317.33	0.8391	0.0002	Accept H0
La Bocana	-66	-0.0387	23374	0.6707	-0.0023	Accept H0
Maneadero	-36	-0.0210	23382.67	0.8190	-0.0010	Accept H0
Ojos Negros	-24	-0.0140	23378	0.8804	-0.0006	Accept H0
Olivares Mexicanos	-56	-0.0329	23362	0.7190	-0.0018	Accept H0
Punta Banda	21	0.0123	23379.67	0.8959	0.0011	Accept H0
Real del Castillo	8	0.0047	23372	0.9635	0	Accept H0
San Carlos	-44	-0.0257	23380.67	0.7785	-0.0020	Accept H0
San Rafael	-12	-0.0070	23380.67	0.9427	-0.0002	Accept H0
Santa Isabel	-24	-0.0140	23380.67	0.8804	-0.0007	Accept H0
Santo Tomás	-53	-0.0311	23352.33	0.7336	-0.0018	Accept H0
Sierra de Juárez	36	0.0211	2338	0.8189	0.0016	Accept H0

Table 193 Results of the Mann-Kendall test for mean December precipitation values

Maximum values

Station	Mann Kendall Test					
	S	Tau	Var (S)	p-value	Sen's slope	Test interpretation
Presa ELZ	-93	-0.0545	23372.33	0.5473	-0.0455	Accept H0
Ejido Uruapan	-64	-0.0377	23346.67	0.6801	-0.0302	Accept H0
El Álamo	44	0.0262	23242	0.7779	0	Accept H0
El Ciprés	-49	-0.0288	23365.67	0.7535	-0.0154	Accept H0
El Farito	-71	-0.0417	23366.33	0.6470	-0.0262	Accept H0
Héroes de la Independencia	64	0.0377	23315.33	0.6799	0.0222	Accept H0
La Bocana	-48	-0.0282	23364.67	0.7585	-0.0143	Accept H0
Maneadero	-6	-0.0035	23378.67	0.9739	-0.0024	Accept H0
Ojos Negros	-71	-0.0417	23363.67	0.6470	-0.0294	Accept H0
Olivares Mexicanos	-35	-0.0207	23329	0.8238	0	Accept H0
Punta Banda	81	0.0475	23373.67	0.6008	0.0345	Accept H0
Real del Castillo	35	0.0205	23373	0.8240	0.0191	Accept H0
San Carlos	0	0	23378.67	1	0	Accept H0
San Rafael	32	0.0188	23372	0.8393	0.0091	Accept H0
Santa Isabel	8	0.0047	23374	0.9635	0	Accept H0
Santo Tomás	-12	-0.0071	23319.33	0.9426	0	Accept H0
Sierra de Juárez	-78	-0.0457	23375.33	0.6145	-0.0364	Accept H0

Table 194 Results of the Mann-Kendall test for maximum December precipitation values

From what can be observed from the tables, the null hypothesis is generally accepted, that is, there is no evidence for existence or non-existence of a trend.

In February, a positive trend was detected in mean and maximum precipitation values of different meteorological station. The trends detected for the mean precipitation values are in the following stations: Ejido Uruapan, El Álamo, Héroes de la Independencia, La Bocana, Ojos Negros, Olivares Mexicanos, Real del Castillo, San Rafael, Santa Isabel, Santo Tomás and Sierra de Juárez (figures 8 to 18). As for the maximum precipitation values, the stations are: Ejido Uruapan, El Álamo, El Ciprés, La Bocana, Olivares Mexicanos, Real del Castillo, San Rafael and Santa Isabel (figures 19 to 26).

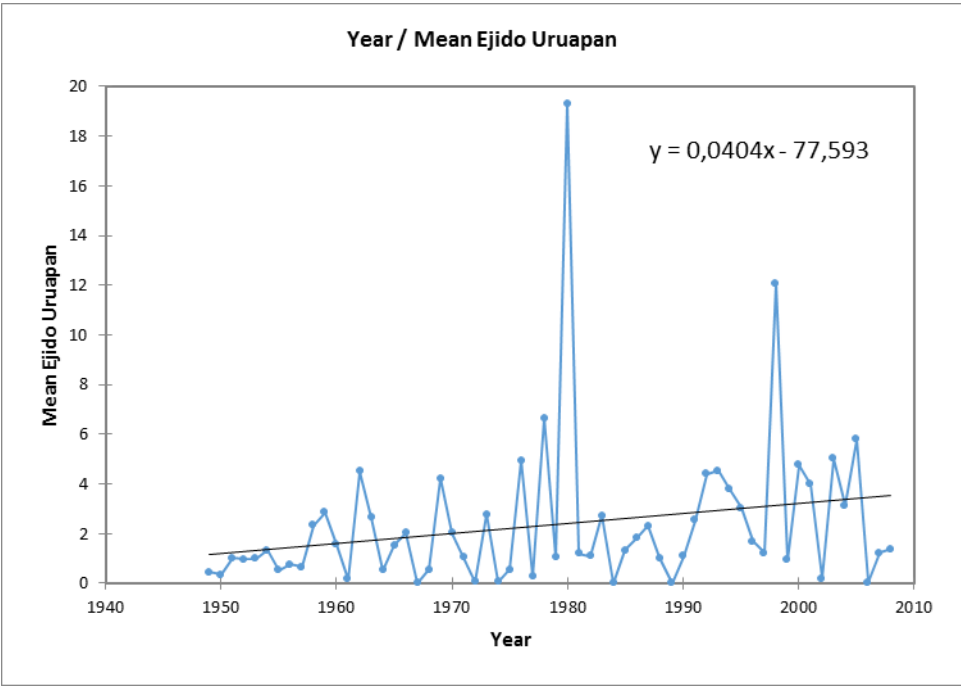


Figure 8 Linear trend line corresponding to mean February precipitation values for Ejido Uruapan station

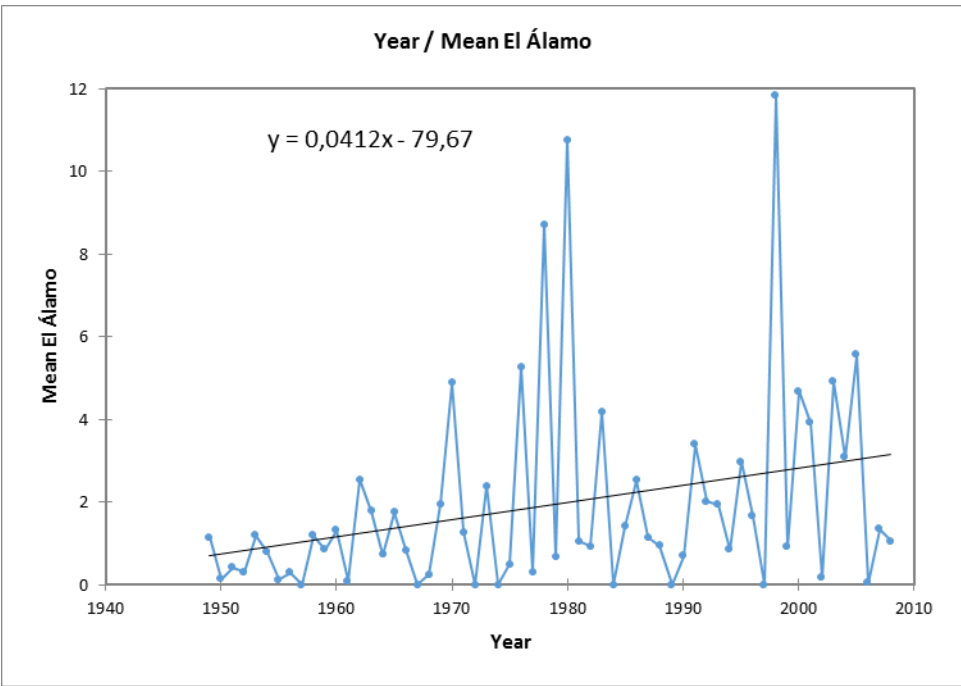


Figure 9 Linear trend line corresponding to mean February precipitation values for El Álamo station

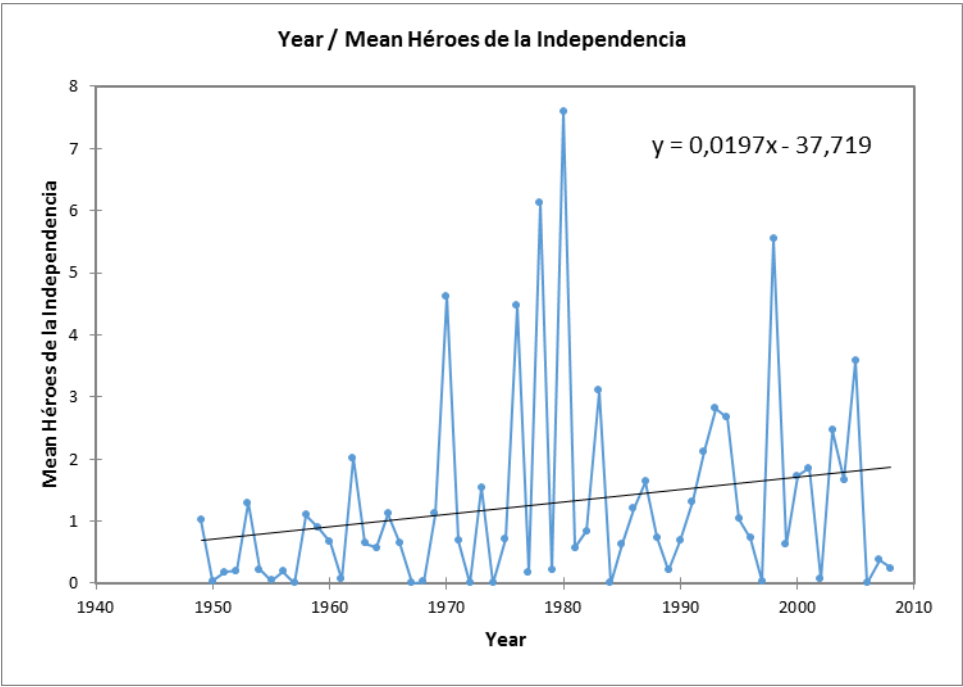


Figure 10 Linear trend line corresponding to mean February precipitation values for Héroes de la Independencia station

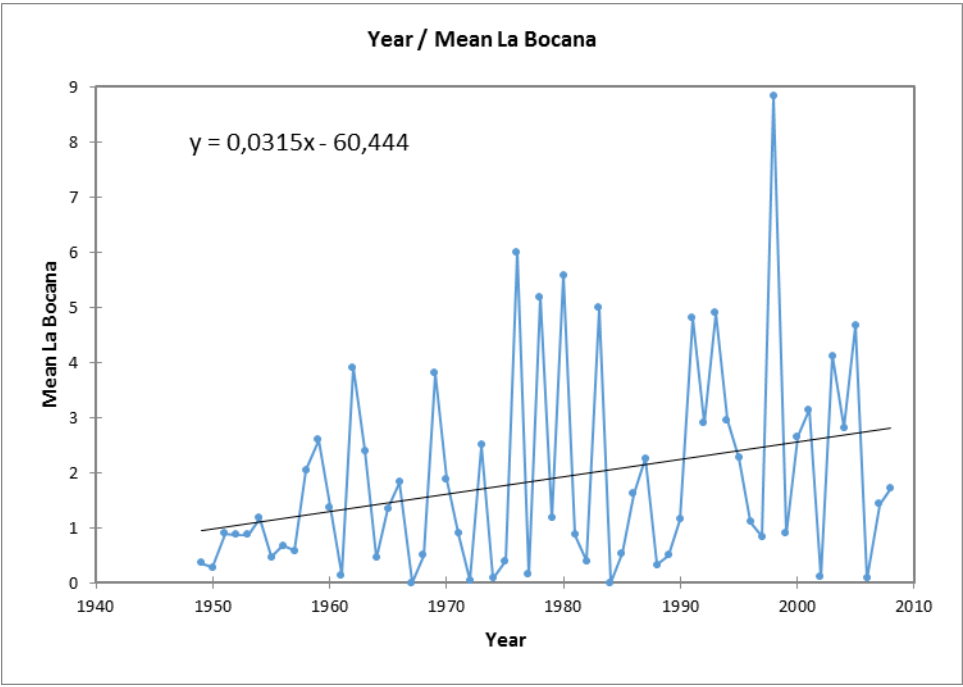


Figure 11 Linear trend line corresponding to mean February precipitation values for La Bocana station

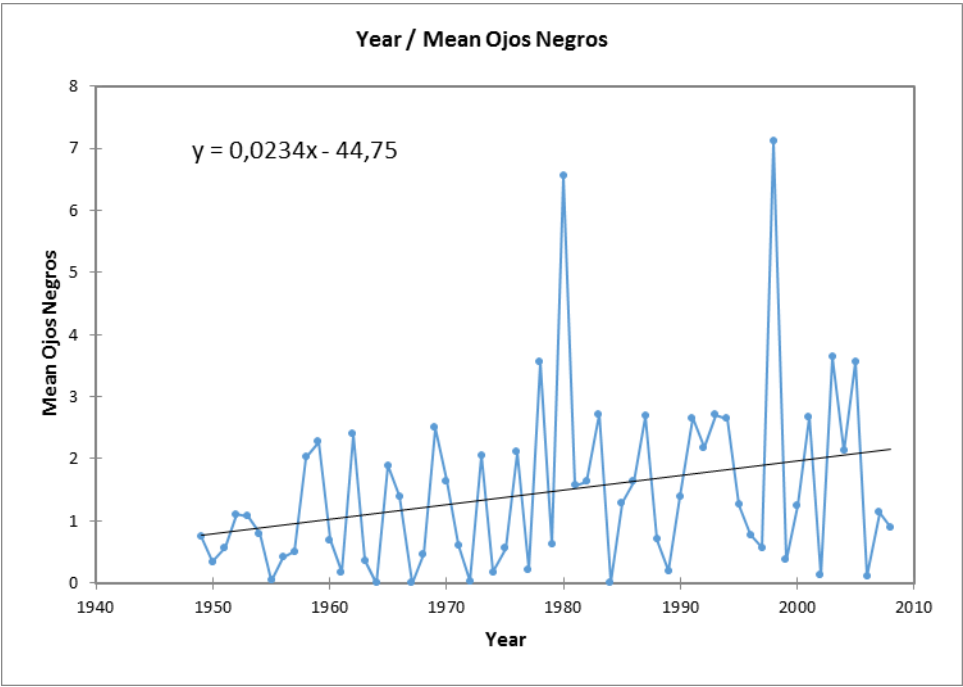


Figure 12 Linear trend line corresponding to mean February precipitation values for Ojos Negros station

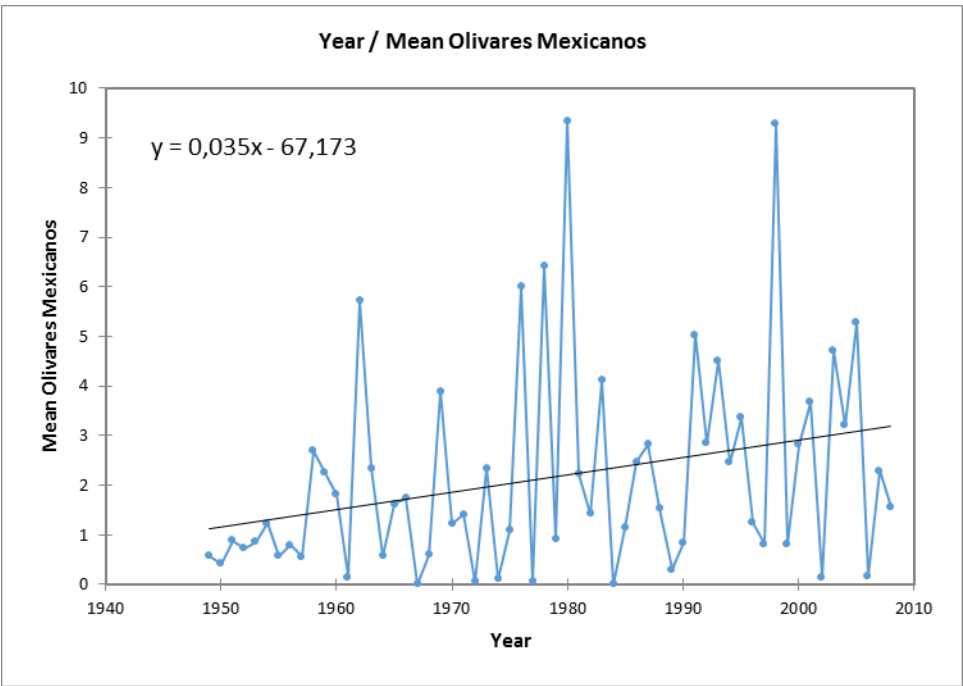


Figure 13 Linear trend line corresponding to mean February precipitation values for Olivares Mexicanos station

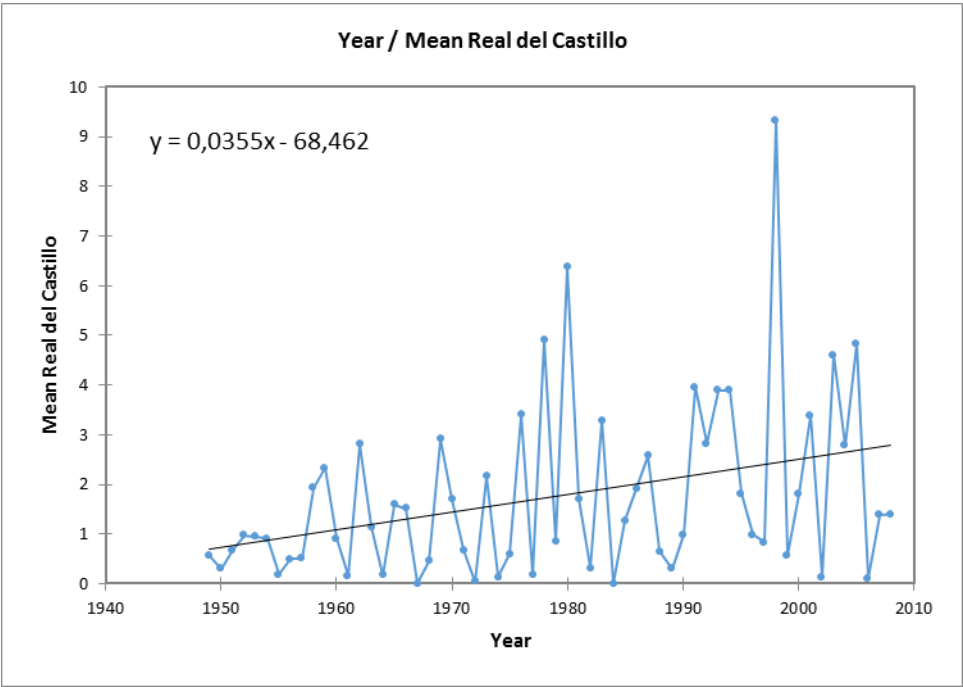


Figure 14 Linear trend line corresponding to mean February precipitation values for Real del Castillo station

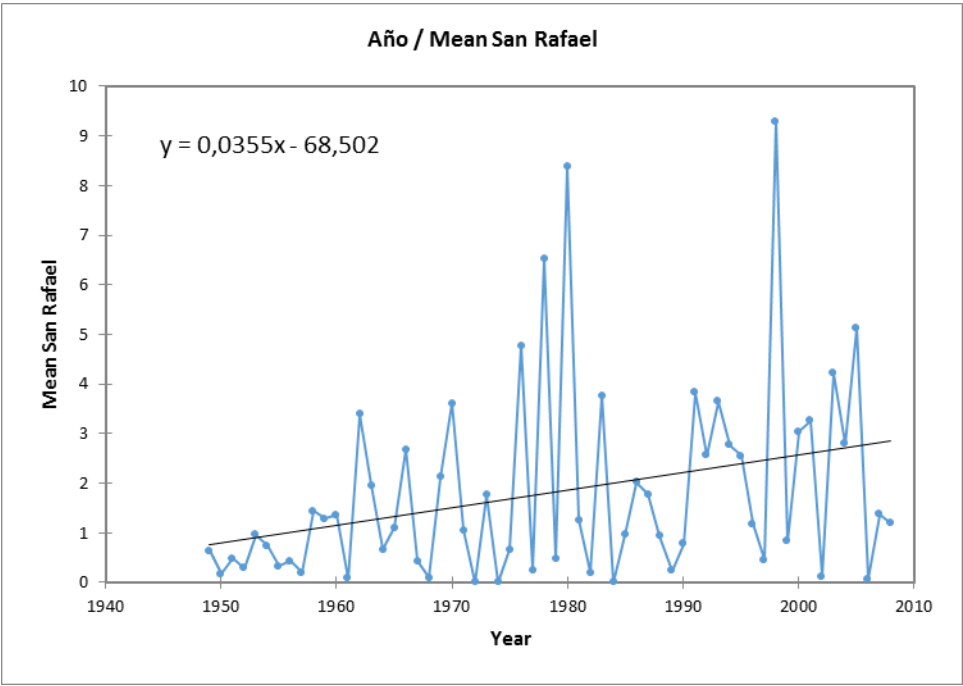


Figure 15 Linear trend line corresponding to mean February precipitation values for San Rafael station

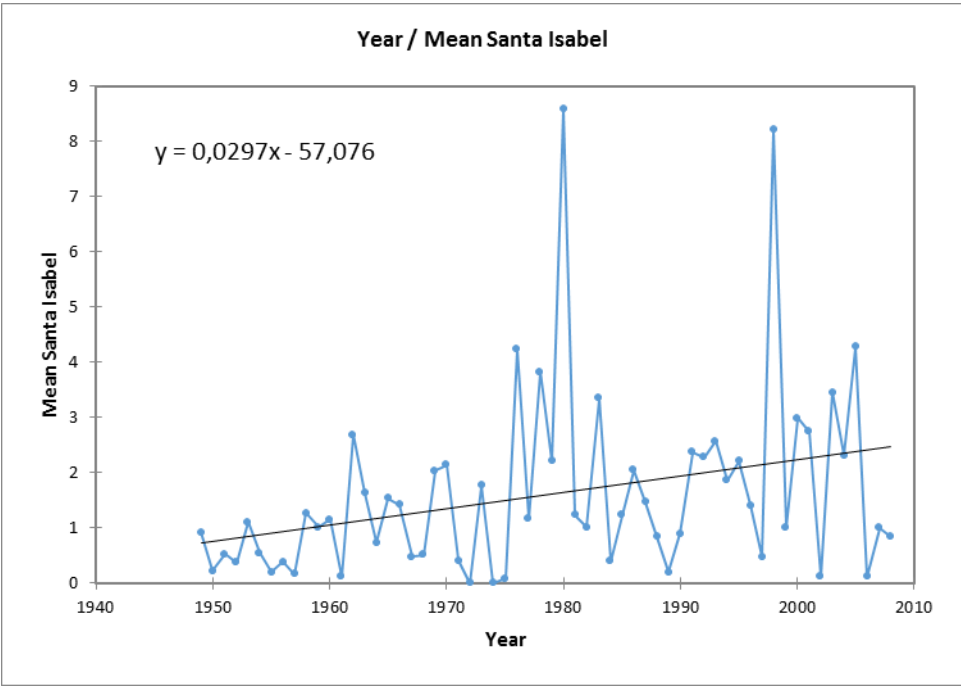


Figure 16 Linear trend line corresponding to mean February precipitation values for Santa Isabel station

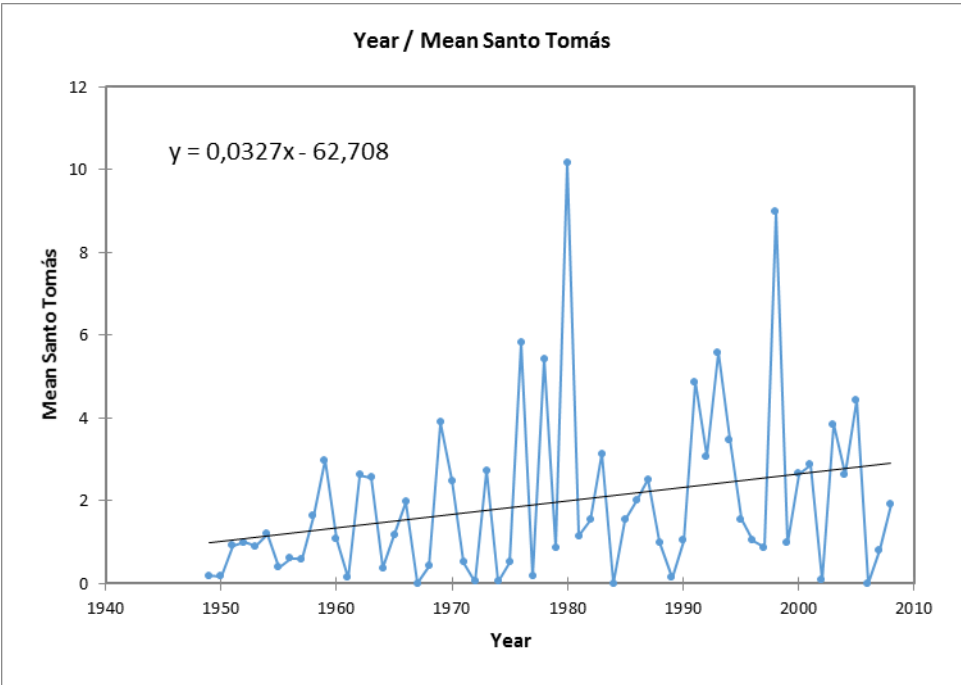


Figure 17 Linear trend line corresponding to mean February precipitation values for Santo Tomás station

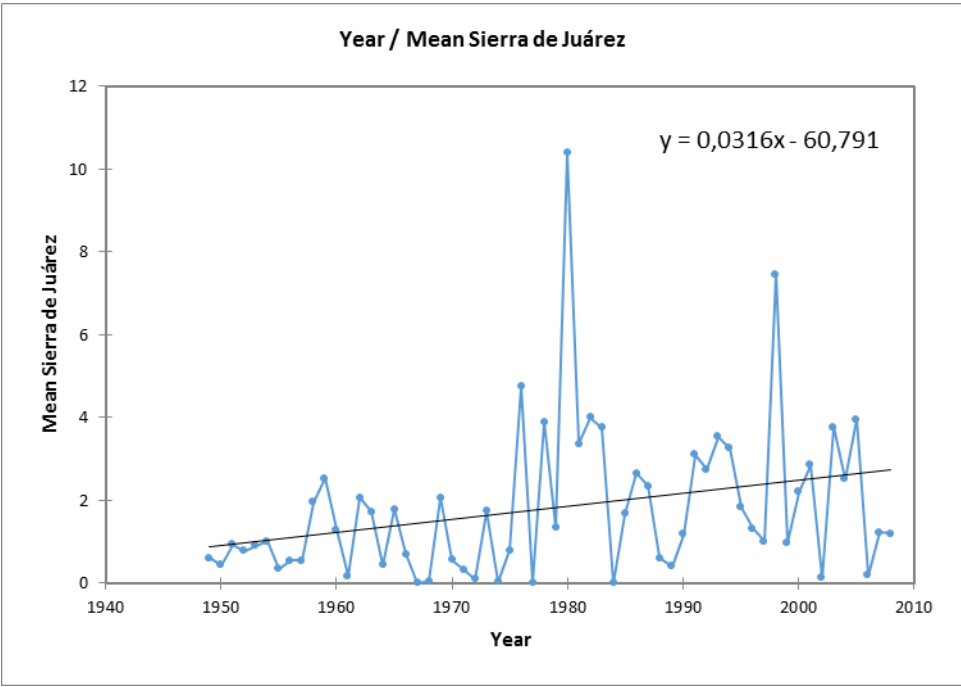


Figure 18 Linear trend line corresponding to mean February precipitation values for Sierra de Juárez station

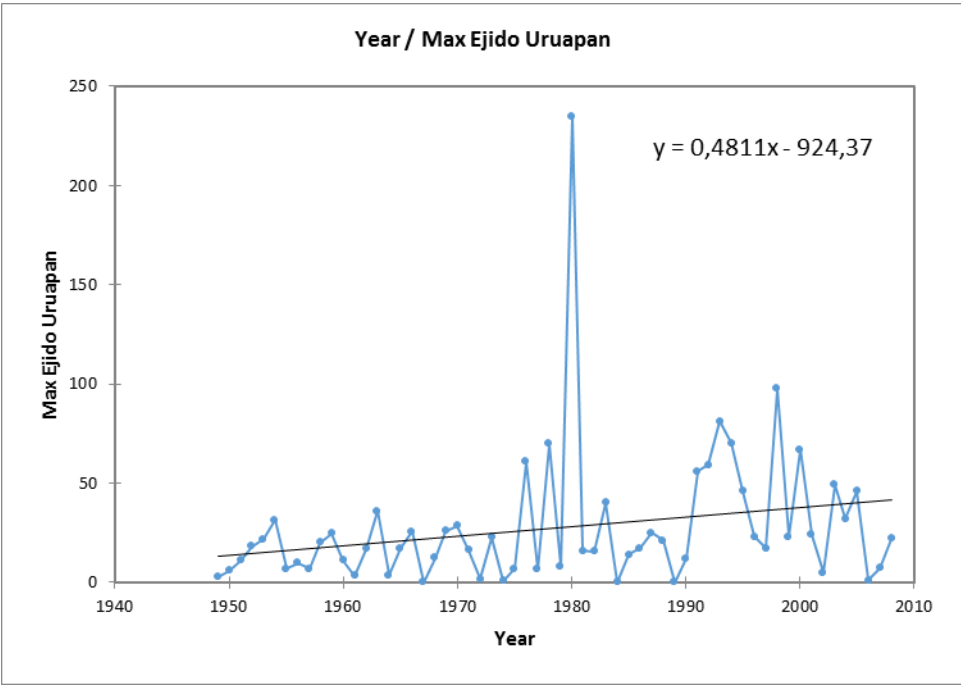


Figure 19 Linear trend line corresponding to maximum February precipitation values for Ejido Uruapan station

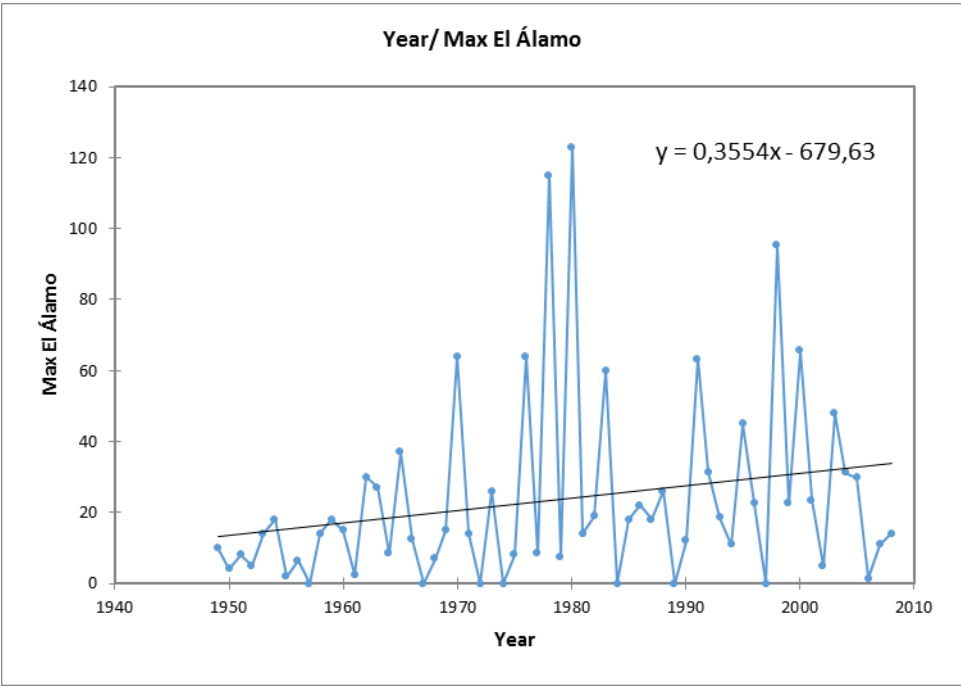


Figure 20 Linear trend line corresponding to maximum February precipitation values for El Álamo station

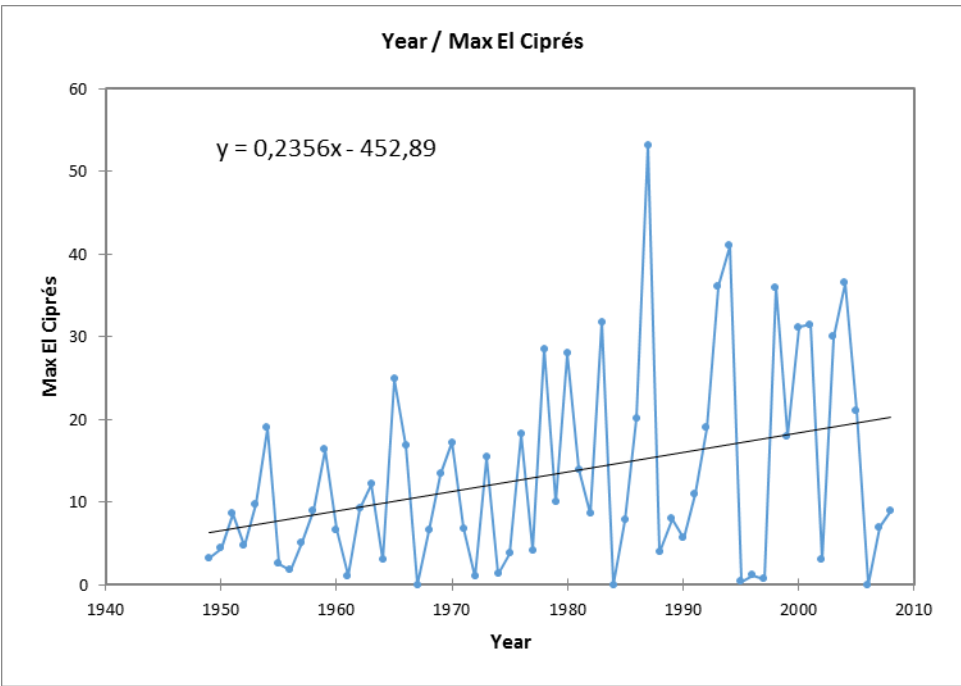


Figure 21 Linear trend line corresponding to maximum February precipitation values for El Ciprés station

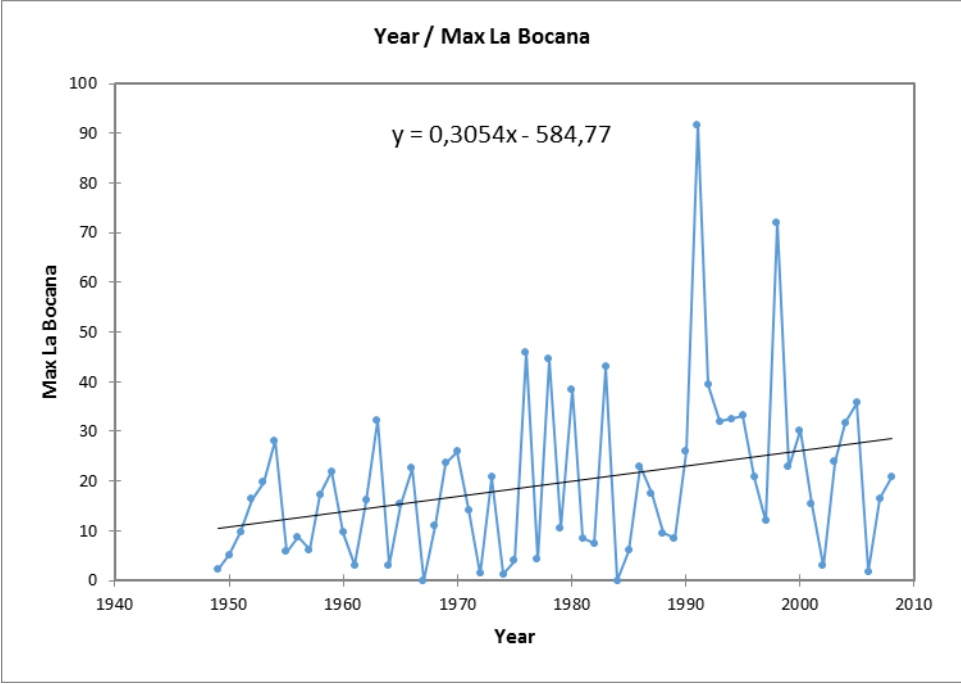


Figure 22 Linear trend line corresponding to maximum February precipitation values for La Bocana station

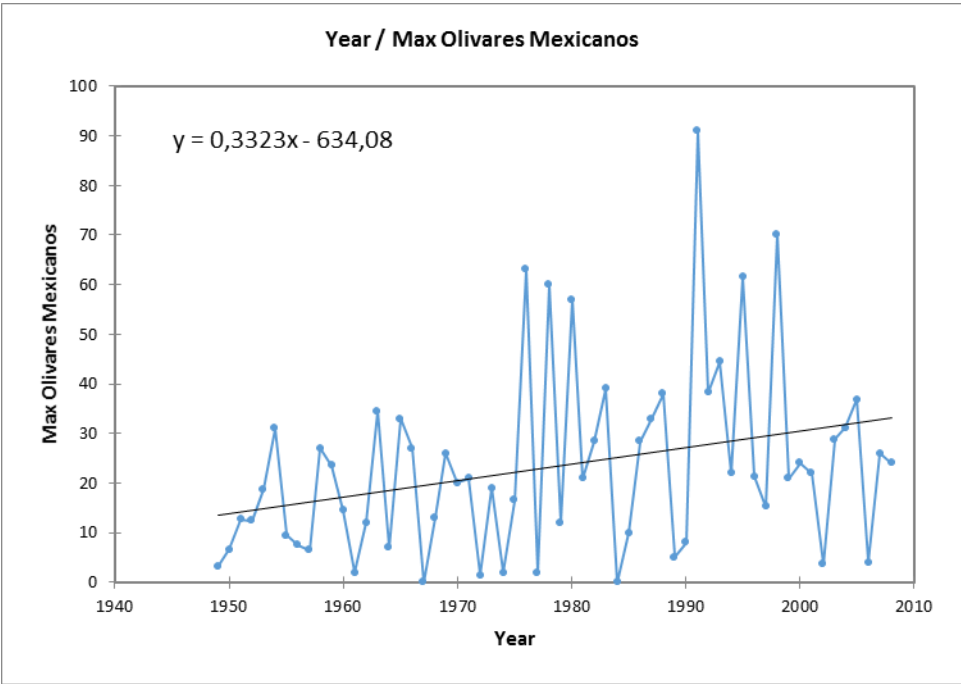


Figure 23 Linear trend line corresponding to maximum February precipitation values for Olivares Mexicanos station

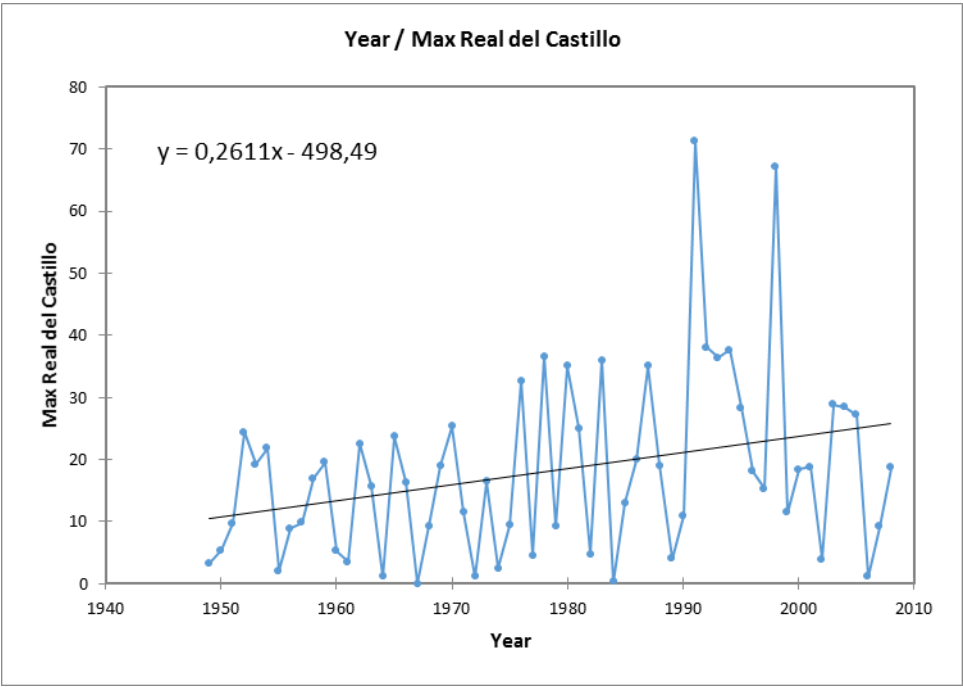


Figure 24 Linear trend line corresponding to maximum February precipitation values for Real del Castillo station

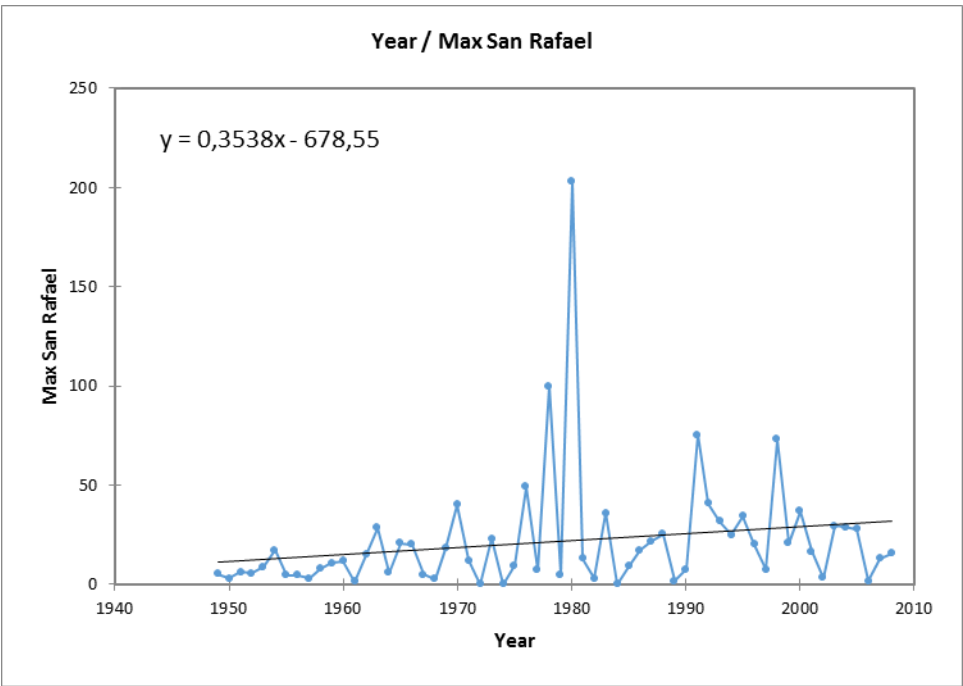


Figure 25 Linear trend line corresponding to maximum February precipitation values for San Rafael station

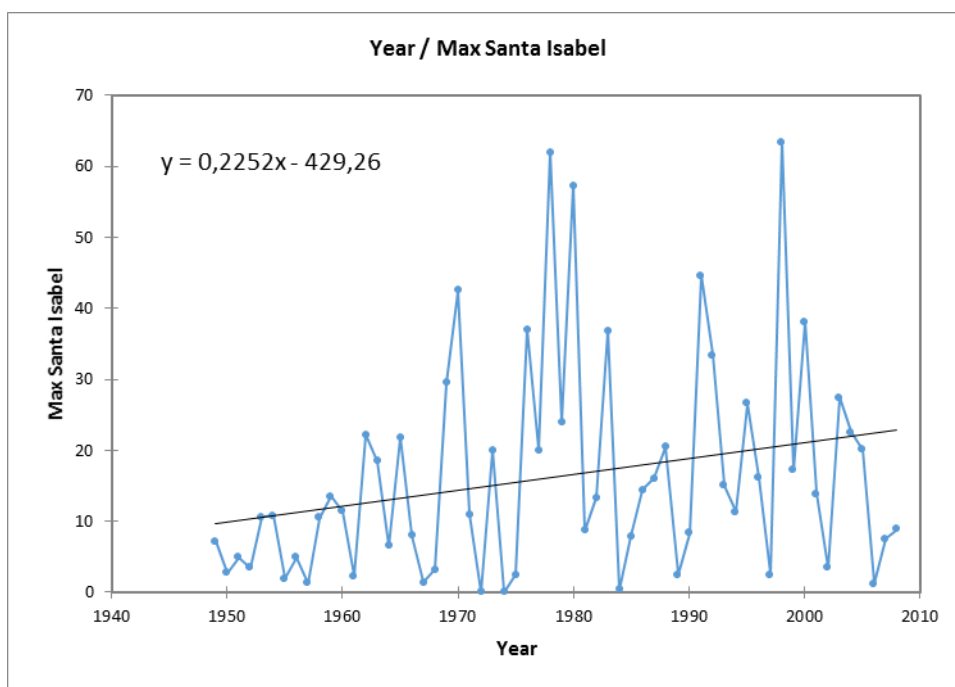


Figure 26 Linear trend line corresponding to maximum February precipitation values for Santa Isabel station

In May, a negative trend has been detected in mean and maximum values for El Ciprés and Punta Banda stations (figures 27 to 30). These trends, though, are small according to Sen's slope result.

In case of the El Ciprés station the mean and maximum precipitation values have a very slight decrease (-0.0003 and -0.0062 respectively according to the Sen's slope). As for the Punta Banda, the same may be said (though the Sen's slope in both cases is 0).

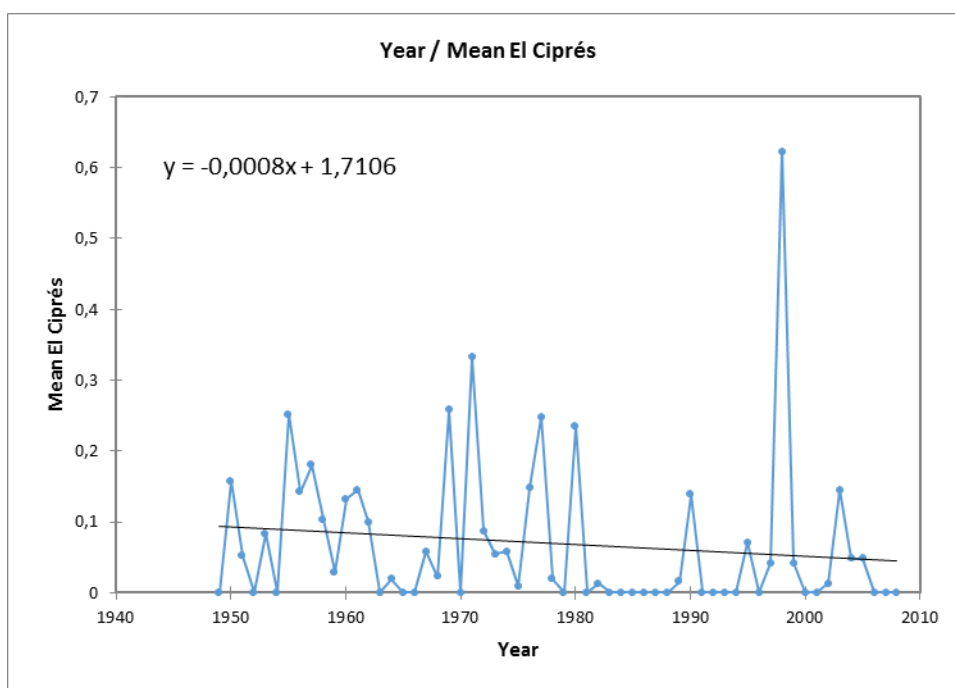


Figure 27 Linear trend line corresponding to mean May precipitation values for El Ciprés station

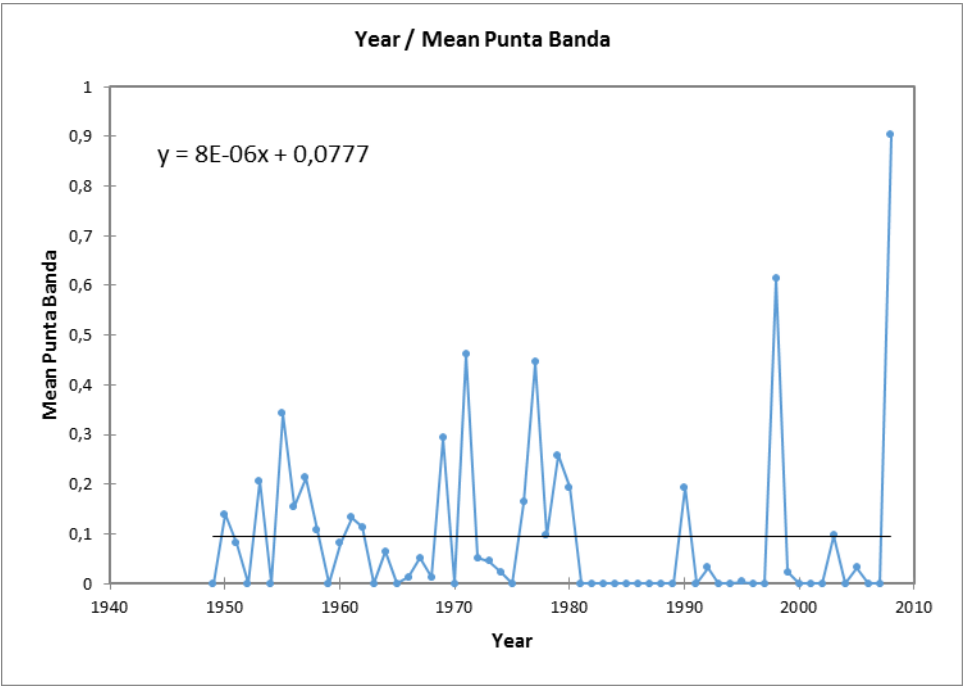


Figure 28 Linear trend line corresponding to mean May precipitation values for Punta Banda station

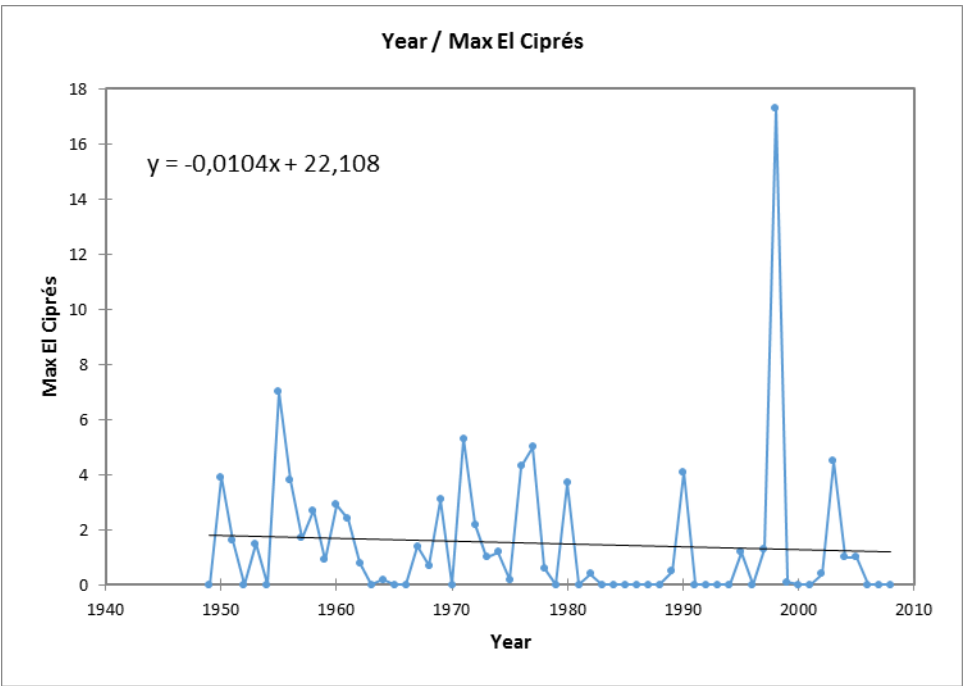


Figure 29 Linear trend line corresponding to maximum May precipitation values for El Ciprés station

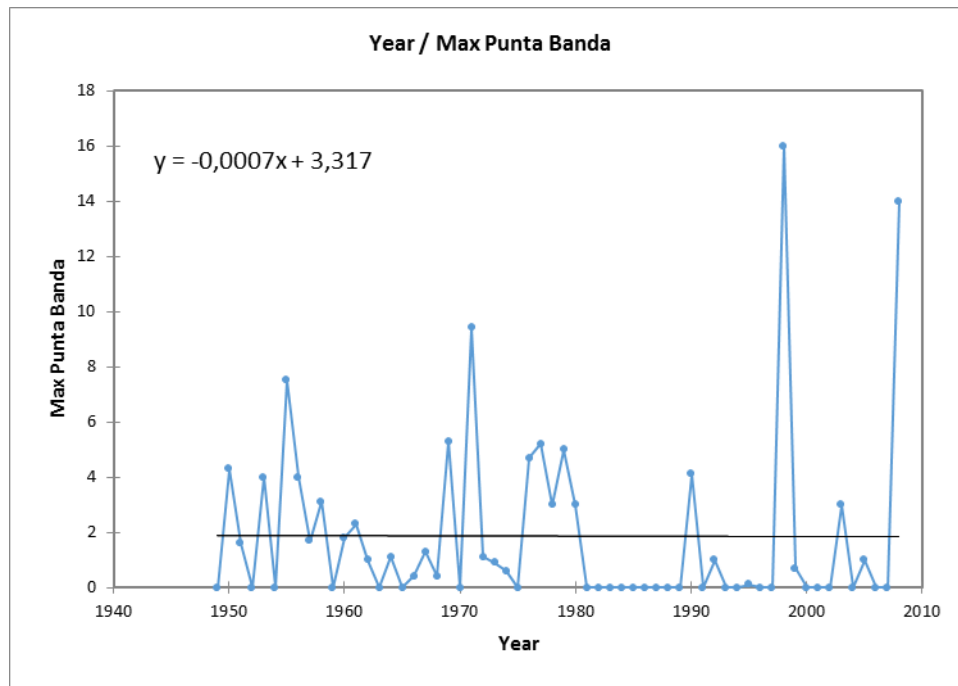


Figure 30 Linear trend line corresponding to maximum May precipitation values for Punta Banda station

In June, a negative trend was detected in mean precipitation values of San Rafael station (Figure 31) and mean and maximum precipitation values of Sierra de Juárez station (Figure 32 and Figure 33, respectively). Those trends are practically insignificant, as Sen's slope result is equal to 0 in all the cases.

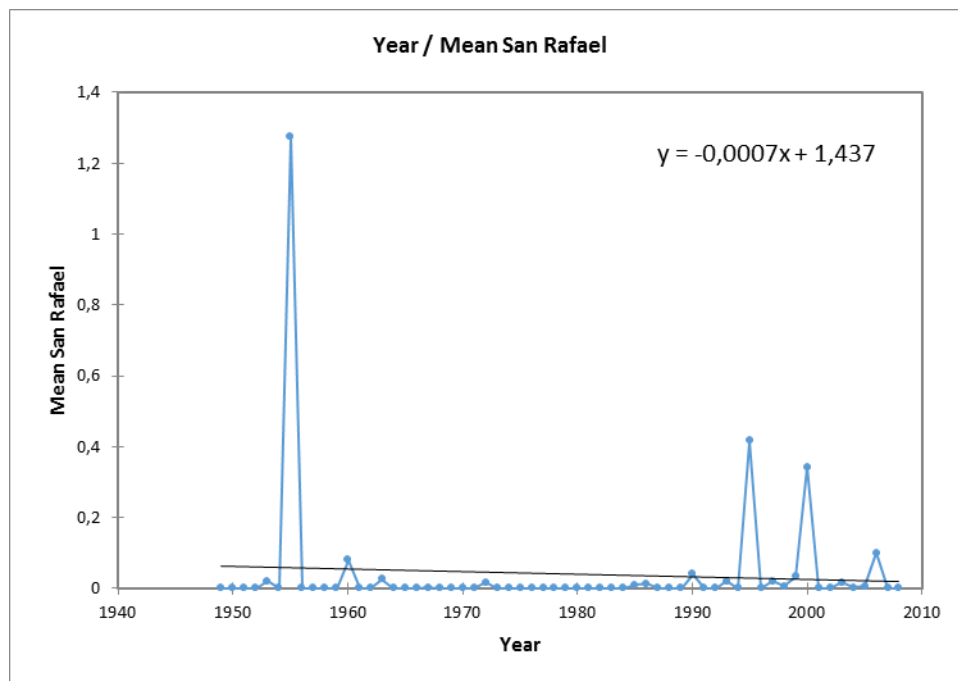


Figure 31 Linear trend line corresponding to mean June precipitation values for San Rafael station

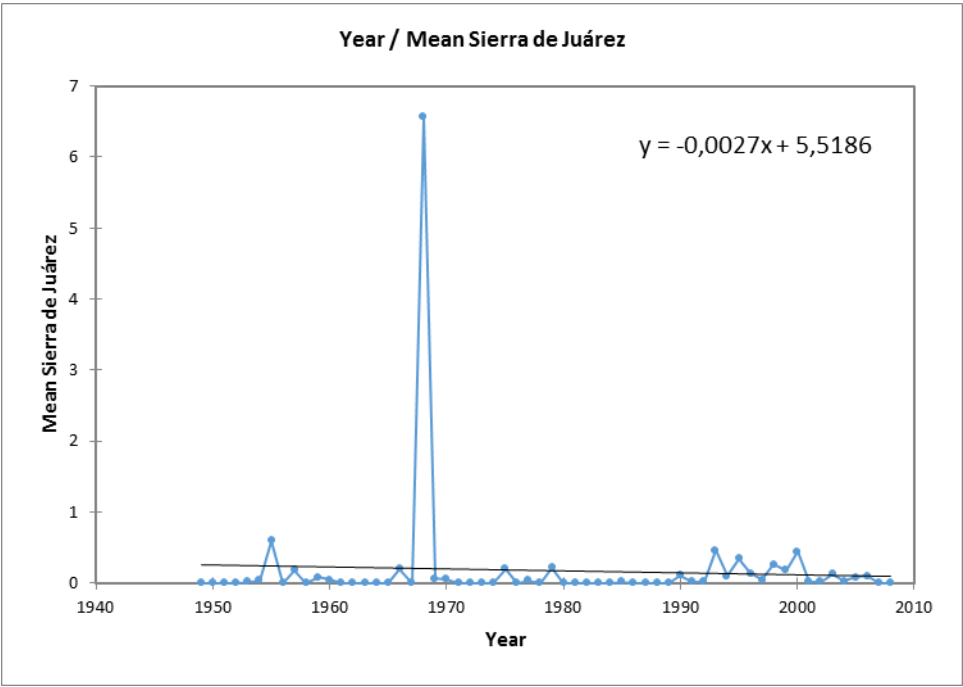


Figure 32 Linear trend line corresponding to mean June precipitation values for Sierra de Juárez station

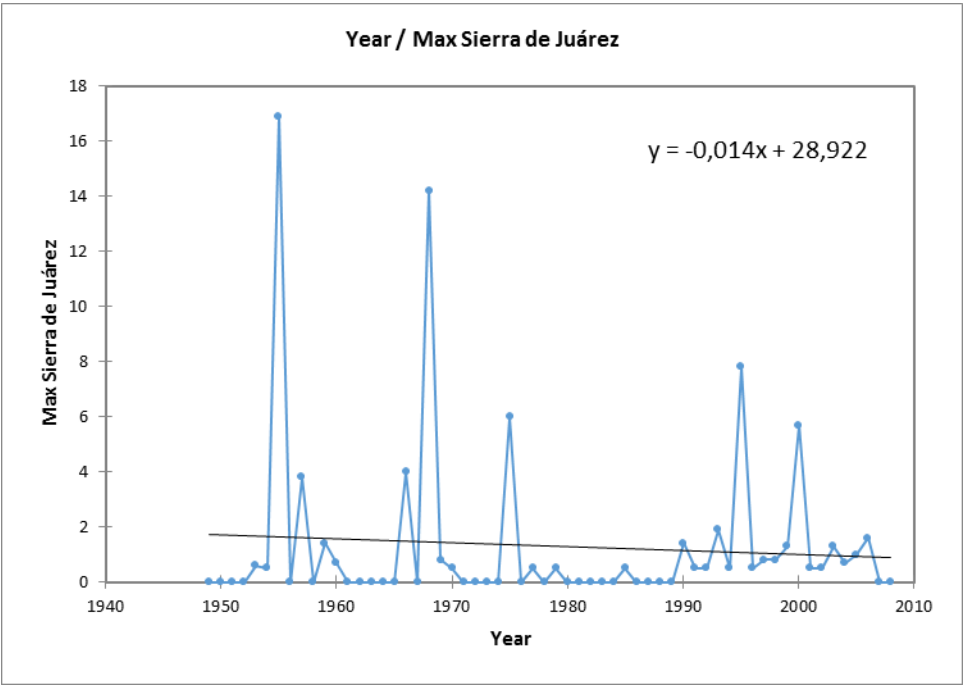


Figure 33 Linear trend line corresponding to maximum June precipitation values for Sierra de Juárez station

In July, a negative trend was detected in the mean and maximum precipitation values of El Ciprés, Maneadero and Punta Banda stations (Figures 34 to 39). The effect of this trend is, yet again, insignificant, as the Sen's slope values are extremely small.

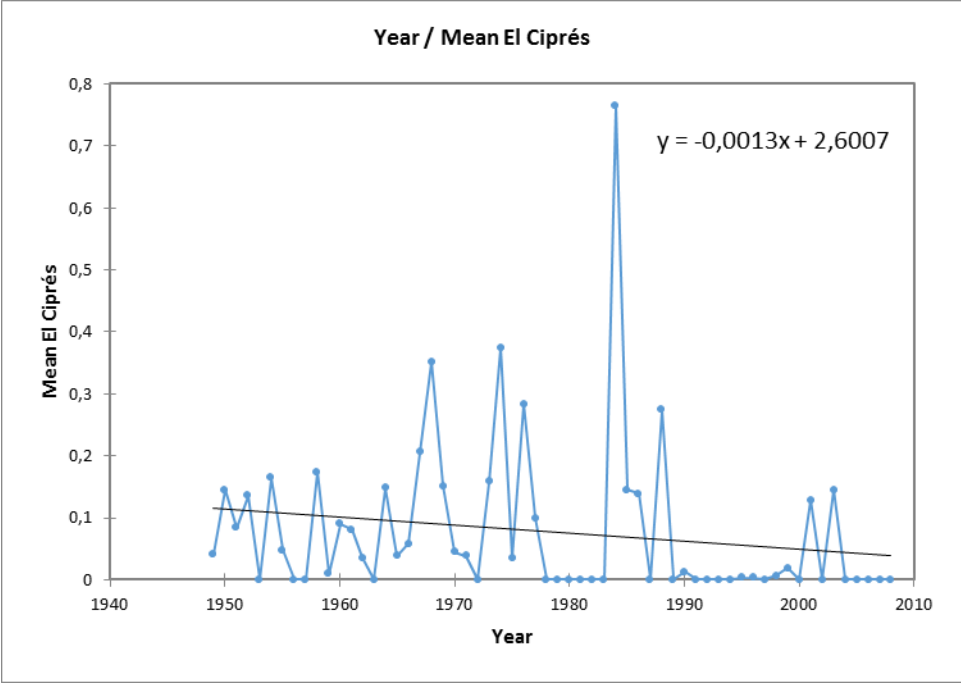


Figure 34 Linear trend line corresponding to mean July precipitation values for El Ciprés station

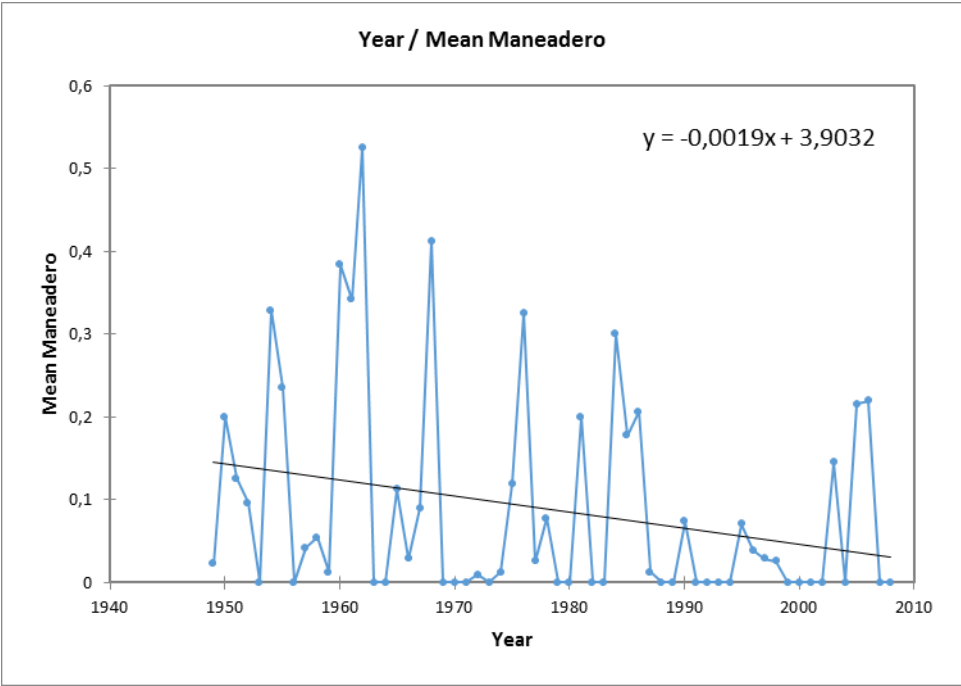


Figure 35 Linear trend line corresponding to mean July precipitation values for Maneadero station

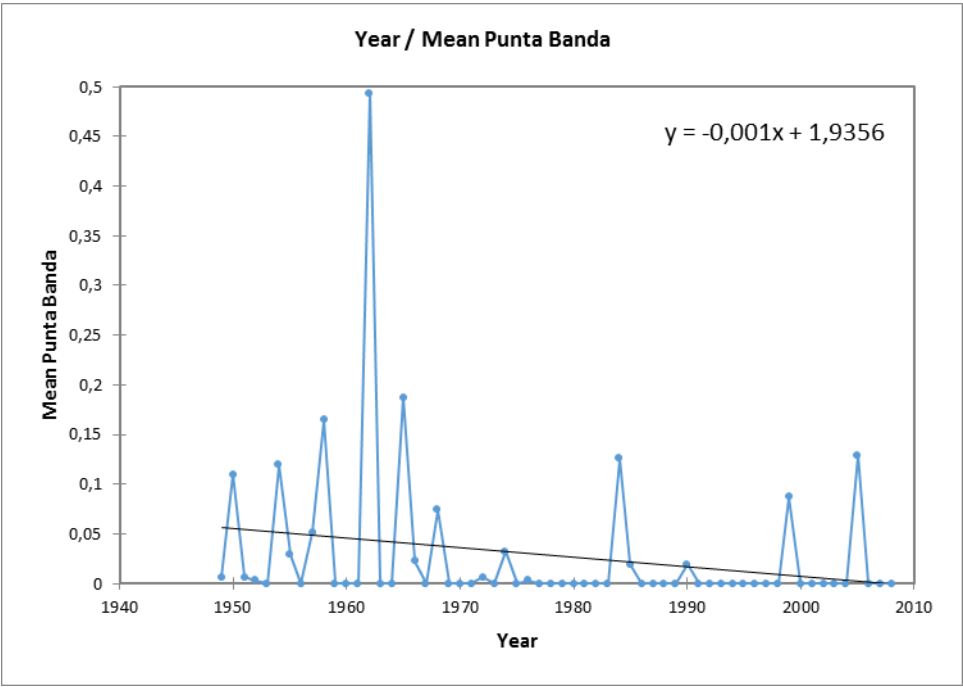


Figure 36 Linear trend line corresponding to mean July precipitation values for Punta Banda station

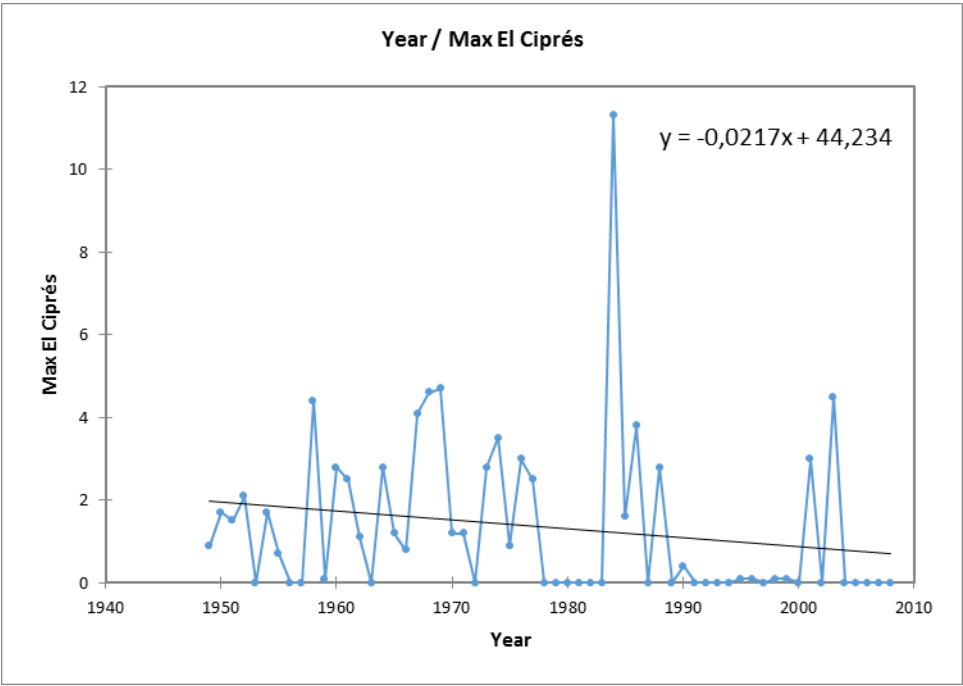


Figure 37 Linear trend line corresponding to maximum July precipitation values for El Ciprés station

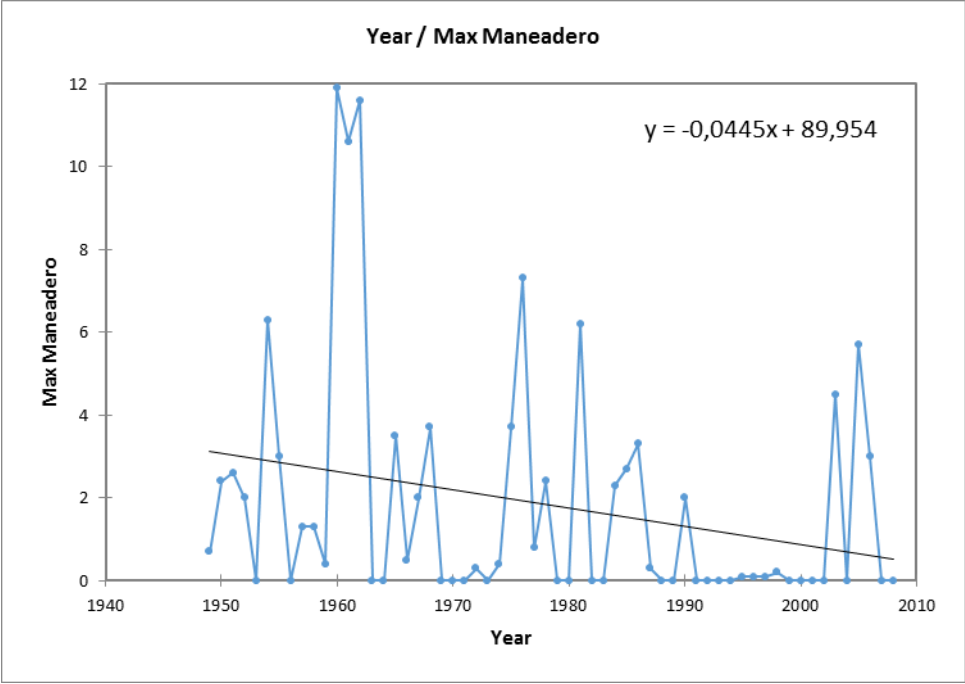


Figure 38 Linear trend line corresponding to maximum July precipitation values for Maneadero station

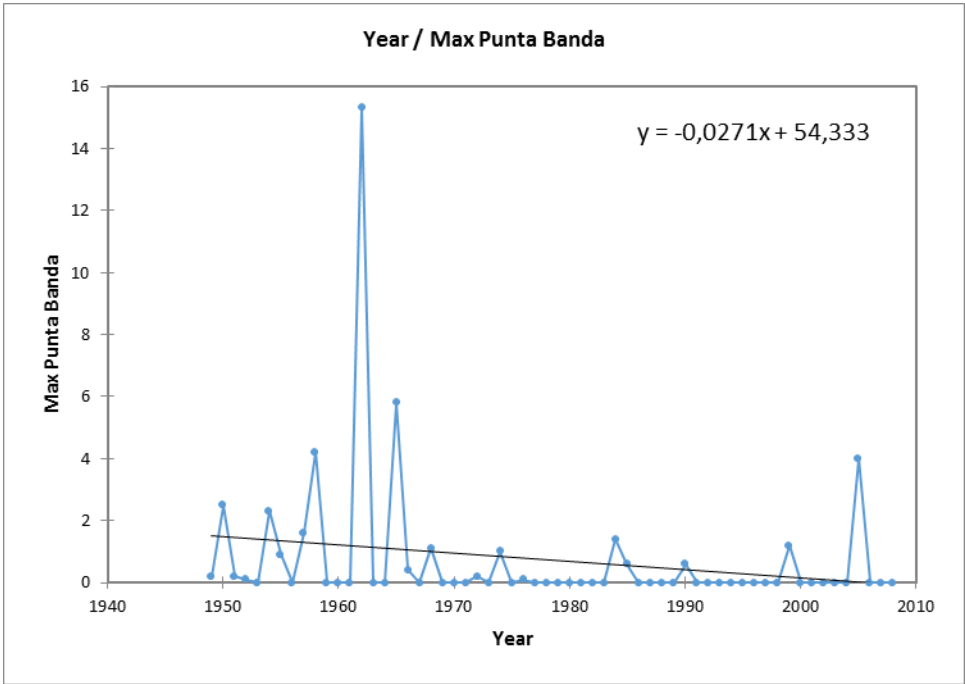


Figure 39 Linear trend line corresponding to maximum July precipitation values for Punta Banda station

In August another negative trend was detected for mean and maximum values of El Ciprés station (Figure 40 and Figure 41, respectively). Yet again, the decline is slight as the Sen's slopes for mean and maximum values are very small (-0.0007 and -0.0125 respectively).

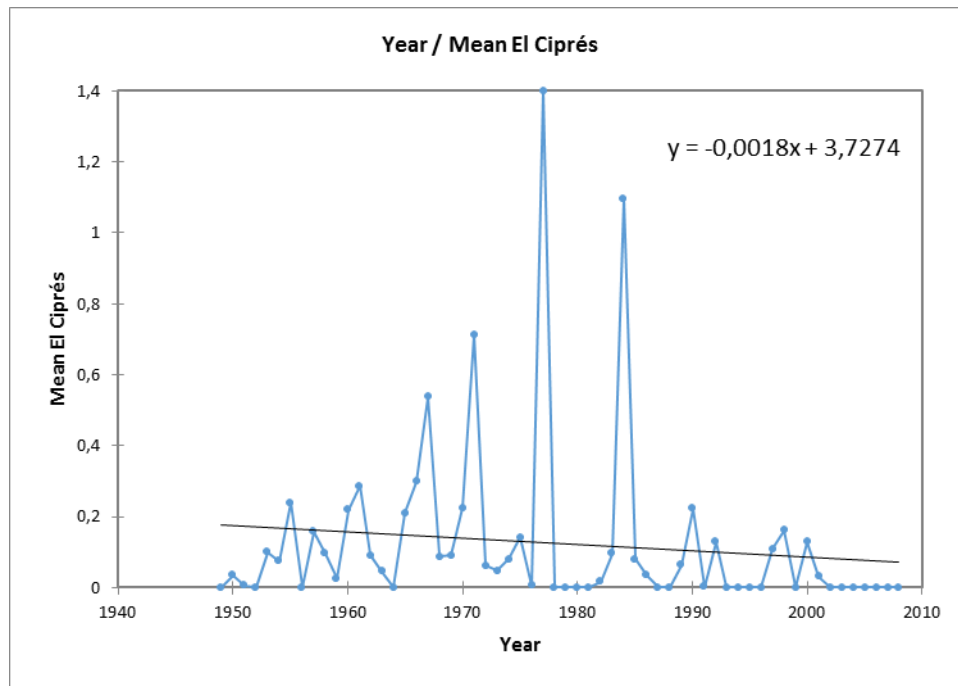


Figure 40 Linear trend line corresponding to mean August precipitation values for El Ciprés station

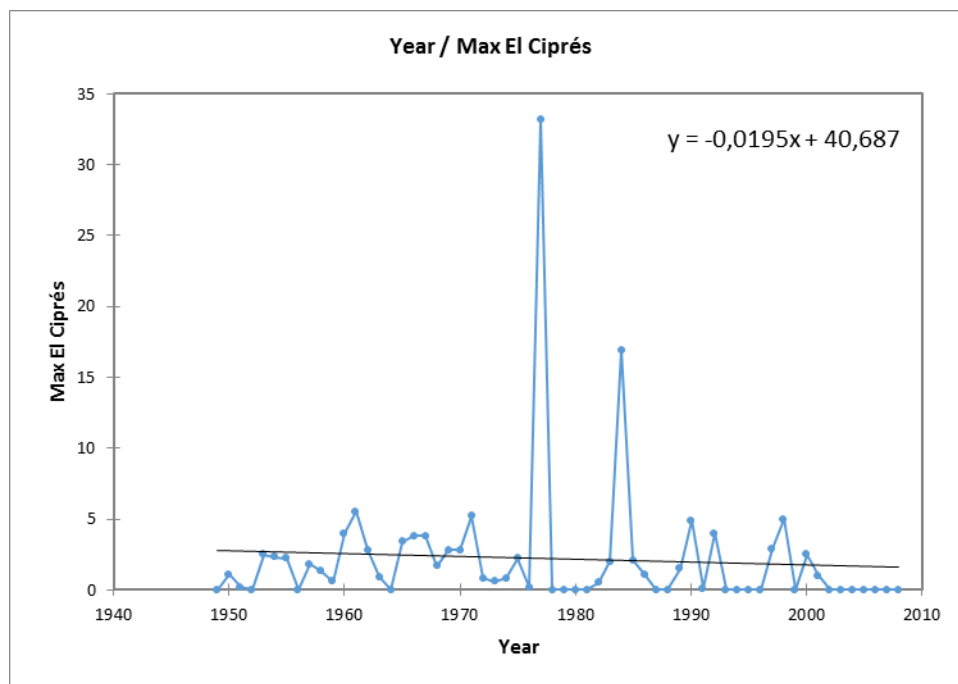


Figure 41 Linear trend line corresponding to maximum August precipitation values for El Ciprés station

In almost all the cases (seasonally as well as monthly segregated), there is no clear evidence of a trend (increasing or decreasing). That is, there is an indication (taking into account the S parameter and the Tau) that trends may be present, but the p-value indicates otherwise. In cases that the p-value does indicate that there is a trend but the Sen's slope is 0, it may be argued that the trend is so small, that it is practically 0.

Had there been more available data or there was a possibility of the restoring the data previous to 1949 or more observations could be accessible from 2008 to present day there would be a possibility to determine whether there is actually a trend or no.

Also, the alpha that was considered is 0.05, that is, it is assumed that 5% of the successes (the mm of precipitation) are due to random causes. Had the alpha been considered of another value (0.01 or 0.1) other results could be expected. Such as, more rejected null hypothesis or less rejected null hypothesis, respectively. Choosing the p-value equal to 0.05 is motivated by previous researches and other scientific literature where this p-value is the most common in use.

For those cases when a trend is present, it may be observed that in the late spring (May-June) and summer (June-August) the precipitations, that are already considered low, have a clear decreasing trend in their mean and maximum values. While for February, one of the rainiest month, the trend is clearly increasing, albeit in small values.

The trends found give an interesting insight, considering the general concerns about water shortage and the need of better water management. From what can be seen, the current/future management should expect less rainfall in the already dry months and slightly more in the “rainier” month.

Correlation with climate indexes

In this chapter the intent was to see if the precipitation has any correlation whatsoever to different climate indexes. Various were tried out just to have a visual of what the said correlation looked like, but the most important index of interest was the el Niño index.

The purpose of running cross-correlation test was to determine if there was any significant relation between the precipitation at the area of study and the el Niño phenomenon and if any, how strong it was and what time interval passed between the events.

An additional note should be made at this point: as various El Niño regions have been demarcated (Figure 42), so the cross-correlation test was run for each of them.

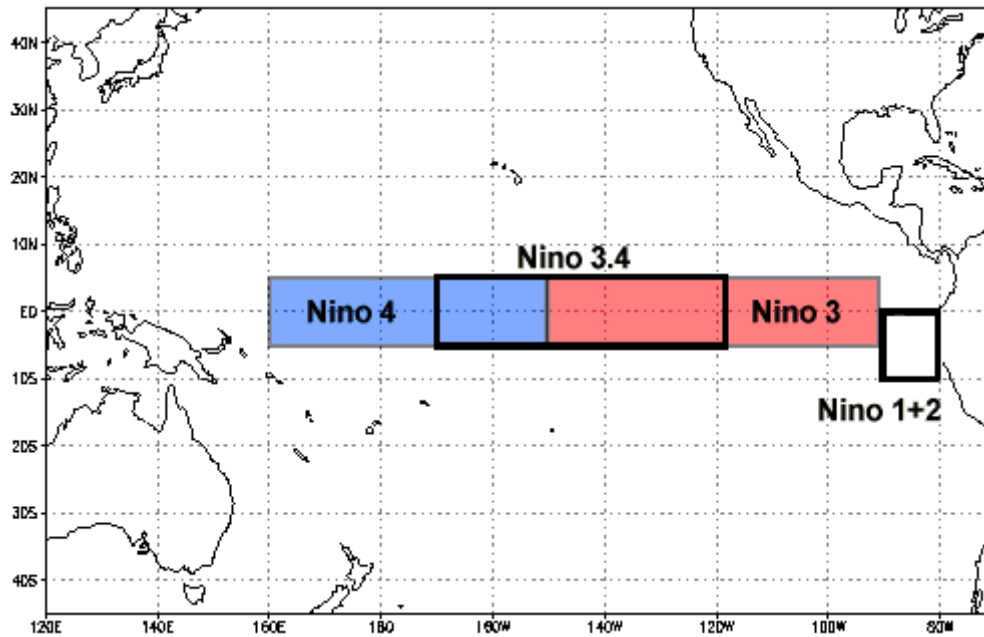


Figure 42 Location of the El Niño indexes registration

The following present the graphs representative of the stations for each index.

El Niño 1+2

The correlation between the El Niño 1+2 index and the mean precipitation values is cyclical. The period between the maximum peaks of correlation is that of 11 to 12 months. The absolute maximum correlation (0.5284) occurs within 1 lag after the El Niño event. That is, the mean precipitation experiences a clear rise in its value 1 month after the maximum values of the El Niño index.

For this particular meteorological station, Presa ELZ (Figure 43), the peak correlation values vary from 0.4427 to 0.5284. For all the other stations, these results are similar: the maximum peaks vary between 0.35 to 0.53.

For all other cross-correlation graphs, see Annex 3.

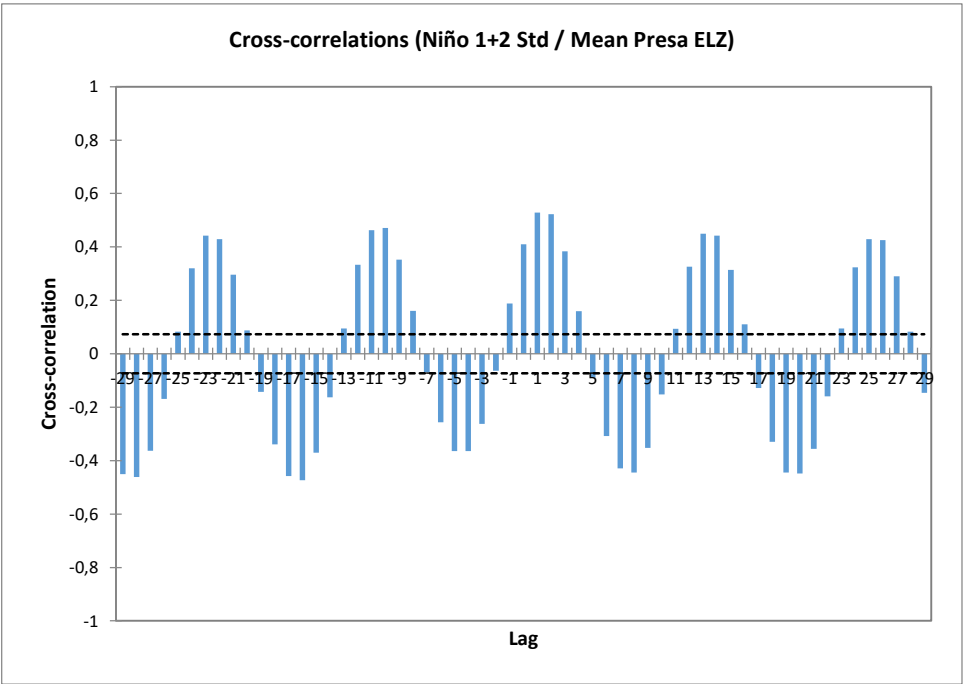


Figure 43 Cross-correlation between the El Niño 1+2 index and mean precipitation values at Presa ELZ station

The only exception to this rule is the Santa Isabel station (Figure 44): no significant correlation was found between the El Niño 1+2 index and the mean precipitation values.

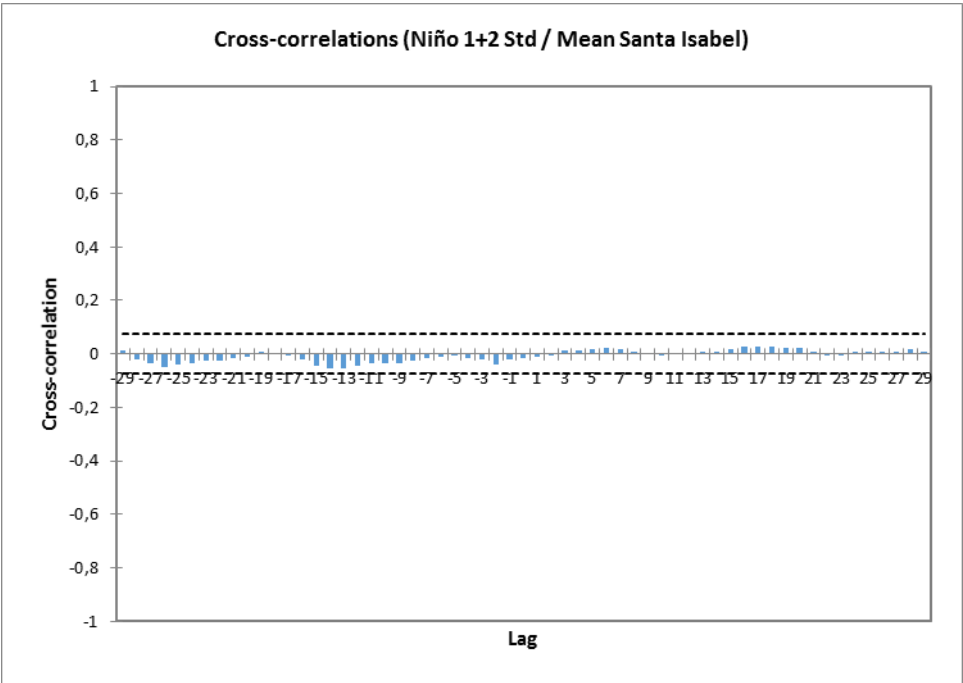


Figure 44 Cross-correlation between the El Niño 1+2 index and mean precipitation values at Santa Isabel station

As for the correlation between the El Niño 1+2 index and the maximum values of precipitation, the same thing may be said about the cycle: the period between the maximum peaks is that of 12 months. The absolute maximum correlation (0.5275), though, occurs within 2 lags of the El Niño event. That is, the maximum precipitation values experience a rise 2 months after the maximum values of the El Niño index is registered.

For this particular meteorological station, Presa ELZ (Figure 45), the peak correlation values vary from 0.4557 to 0.5275. For all the other stations, these results are similar: the maximum peaks vary between 0.35 to 0.53.

For all other cross-correlation graphs, see Annex 3.

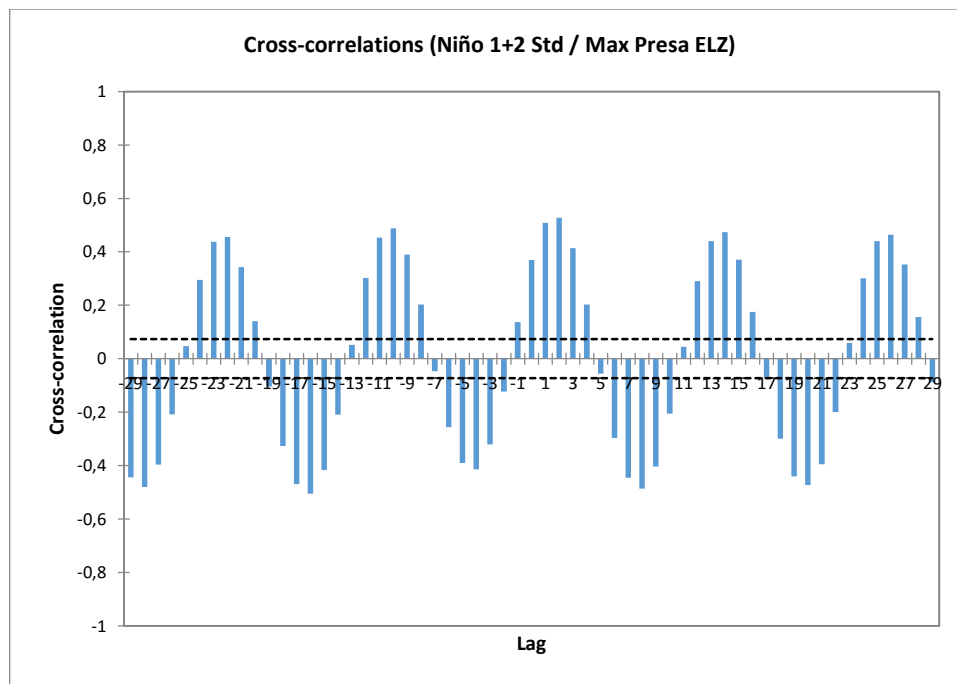


Figure 45 Cross-correlation between the El Niño 1+2 index and maximum precipitation values at Presa ELZ station

Again, the only exception to this rule is the Santa Isabel station (Figure 46): no significant correlation was found between the El Niño 1+2 index and the maximum precipitation values.

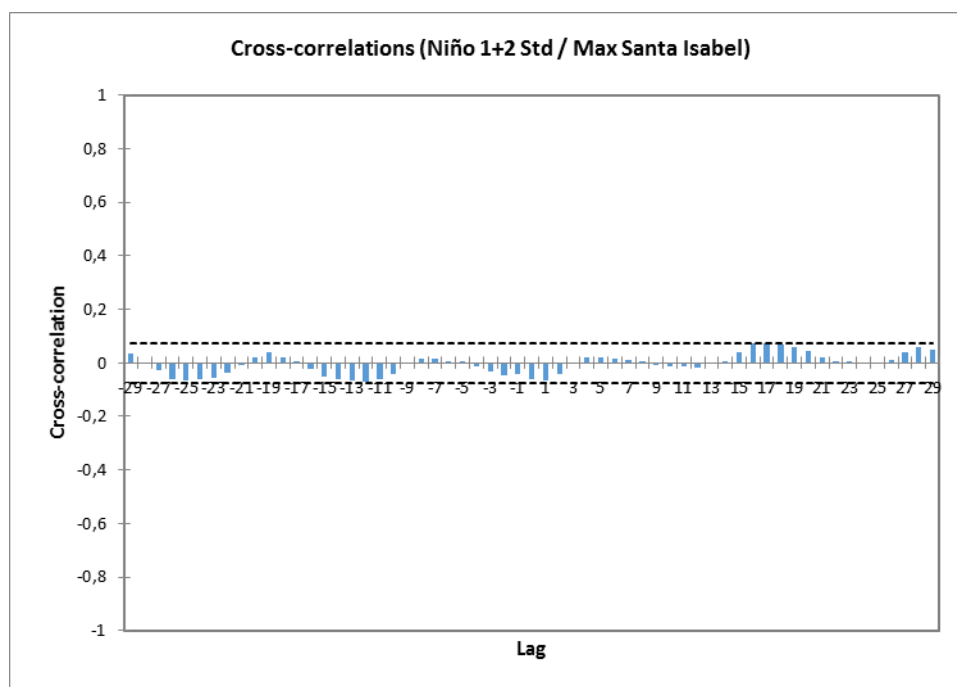


Figure 46 Cross-correlation between the El Niño 1+2 index and maximum precipitation values at Santa Isabel station

El Niño 3

As can be seen from the results, the correlation between the El Niño 3 index and the mean precipitation values is cyclical. The period between the maximum peaks of correlation is that of 11 to 13 months. The absolute maximum correlation (0.4720) occurs within 2 lag after the El Niño event. That is, the mean precipitation experiences a clear rise in its value 2 months after the maximum values of the El Niño index.

For this particular meteorological station, San Carlos (Figure 47), the peak correlation values vary from 0.3416 to 0.4720. For all the other stations, these results are similar: the maximum peaks vary between 0.33 to 0.47.

For all other cross-correlation graphs, see Annex 3.

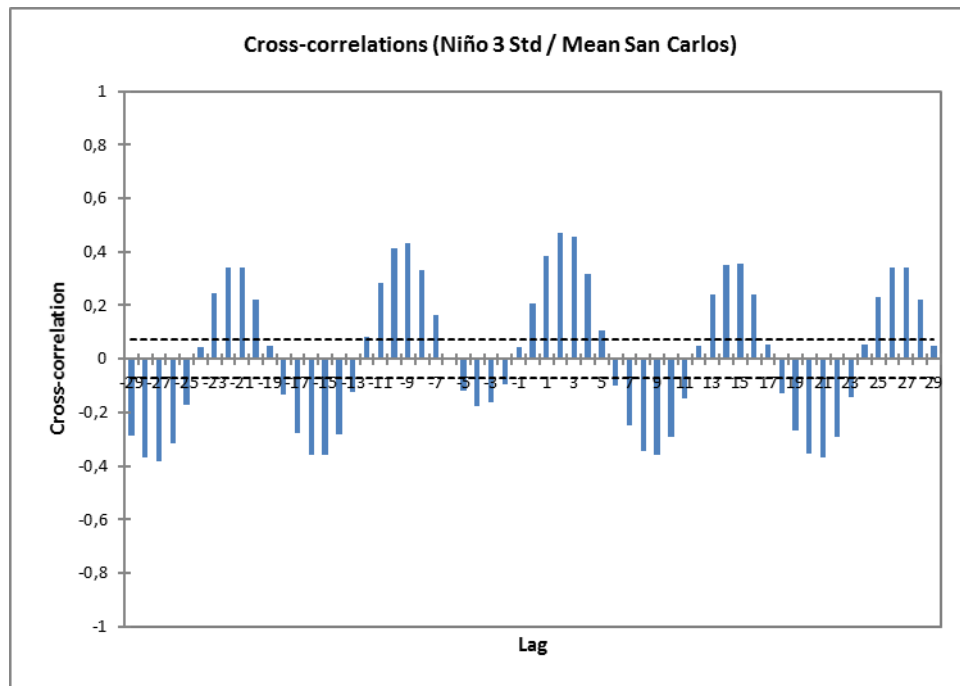


Figure 47 Cross-correlation between the El Niño 3 index and mean precipitation values at San Carlos station

The only exception to this rule is the Santa Isabel station (Figure 48): no significant correlation was found between the El Niño 3 index and the mean precipitation values.

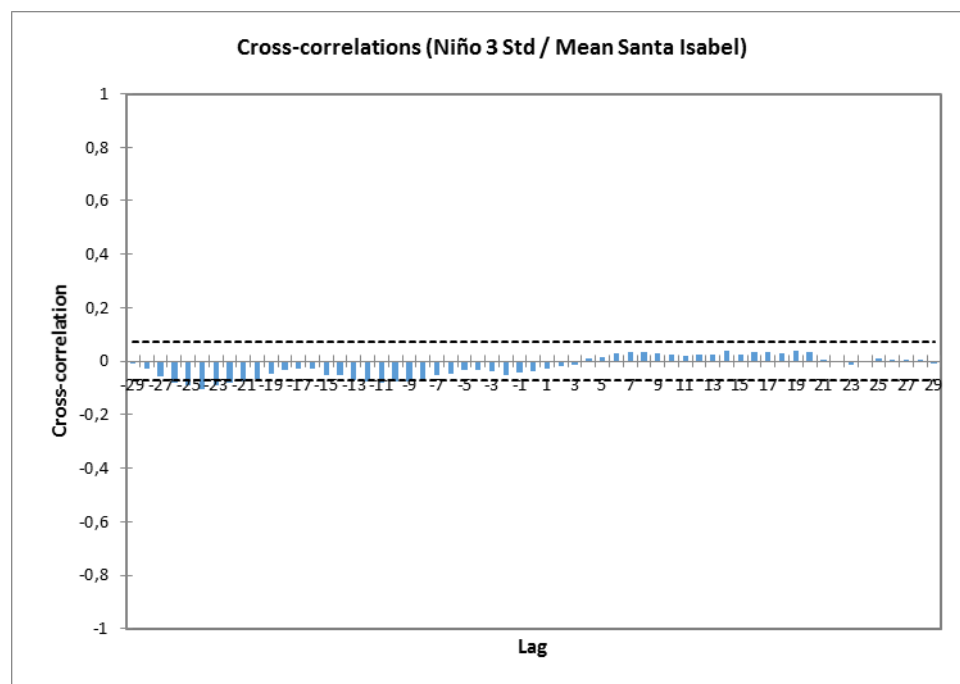


Figure 48 Cross-correlation between the El Niño 3 index and mean precipitation values at Santa Isabel station

As for the correlation between the El Niño 3 index and the maximum values of precipitation, the same thing may be said about the cycle: the period between the maximum peaks is that of 12 months. The absolute maximum correlation (0.4671), though, occurs within 3 lags of the El Niño

event. That is, the maximum precipitation values experience a rise 3 months after the maximum values of the El Niño index is registered.

For this particular meteorological station, San Carlos (Figure 49), the peak correlation values vary from 0.3695 to 0.4671. For all the other stations, these results are similar: the maximum peaks vary between 0.30 to 0.47.

For all other cross-correlation graphs, see Annex 3.

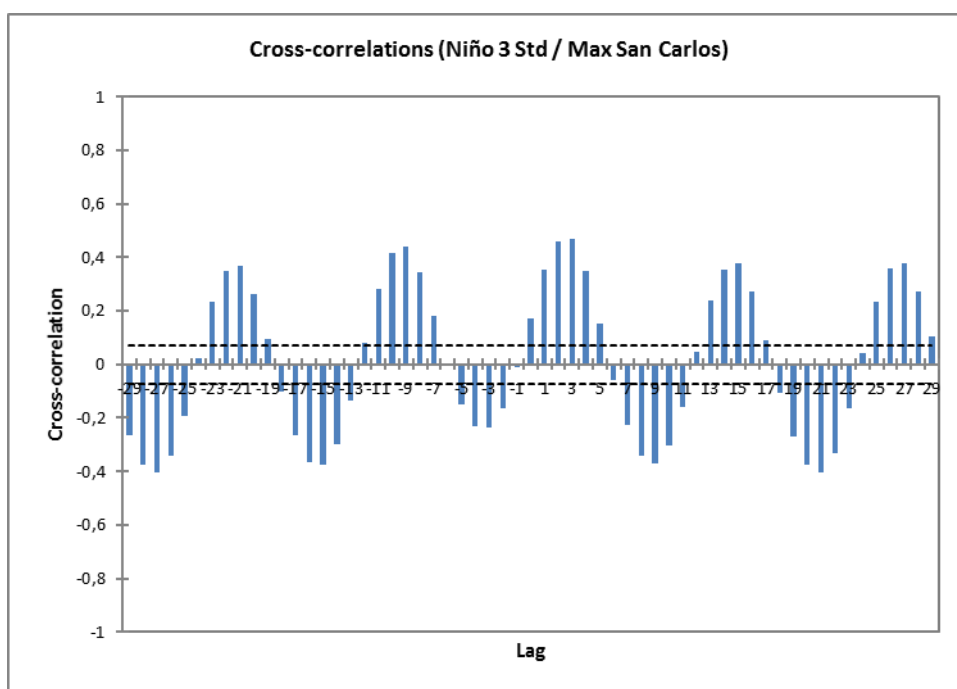


Figure 49 Cross-correlation between the El Niño 3 index and maximum precipitation values at San Carlos station

Yet again, the only exception to this rule is the Santa Isabel station (Figure 50): no significant correlation was found between the El Niño 3 index and the maximum precipitation values.

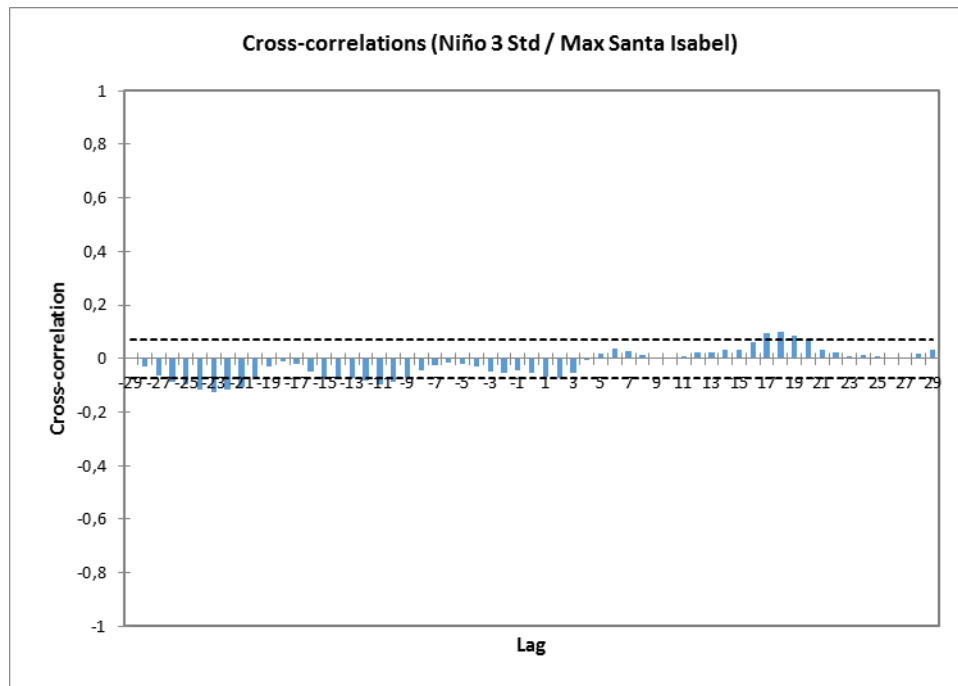


Figure 50 Cross-correlation between the El Niño 3 index and maximum precipitation values at Santa Isabel station

El Niño 3.4

From what has been seen from the results, the correlation between the El Niño 3.4 index and the mean precipitation values is cyclical. The period between the maximum peaks of correlation is that of 11 to 13 months. The absolute maximum correlation (0.3426) occurs within 3 lag after the El Niño event. That is, the mean precipitation experiences a clear rise in its value 3 months after the El Niño index presents its maximum value.

For this particular meteorological station, Real del Castillo (Figure 51), the peak correlation values vary from 0.2164 to 0.3426. For all the other stations, these results are similar: the maximum peaks vary between 0.20 to 0.34.

For all other cross-correlation graphs, see Annex 3.

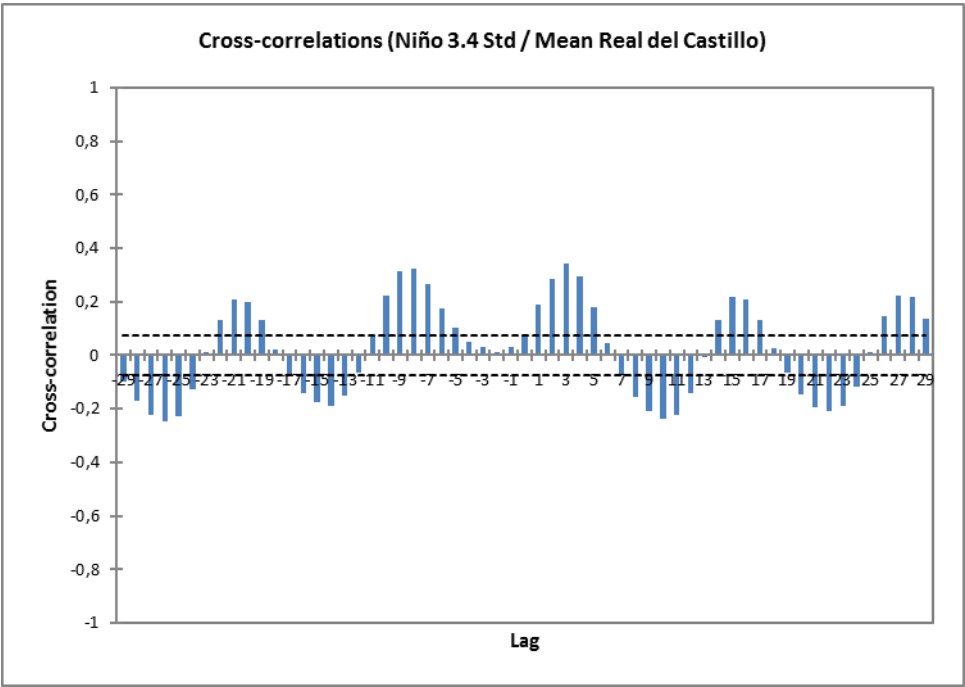


Figure 51 Cross-correlation between the El Niño 3.4 index and mean precipitation values at Real del Castillo station

The only exception to this rule is the Santa Isabel station (Figure 52): no significant correlation was found between the El Niño 3.4 index and the mean precipitation values.

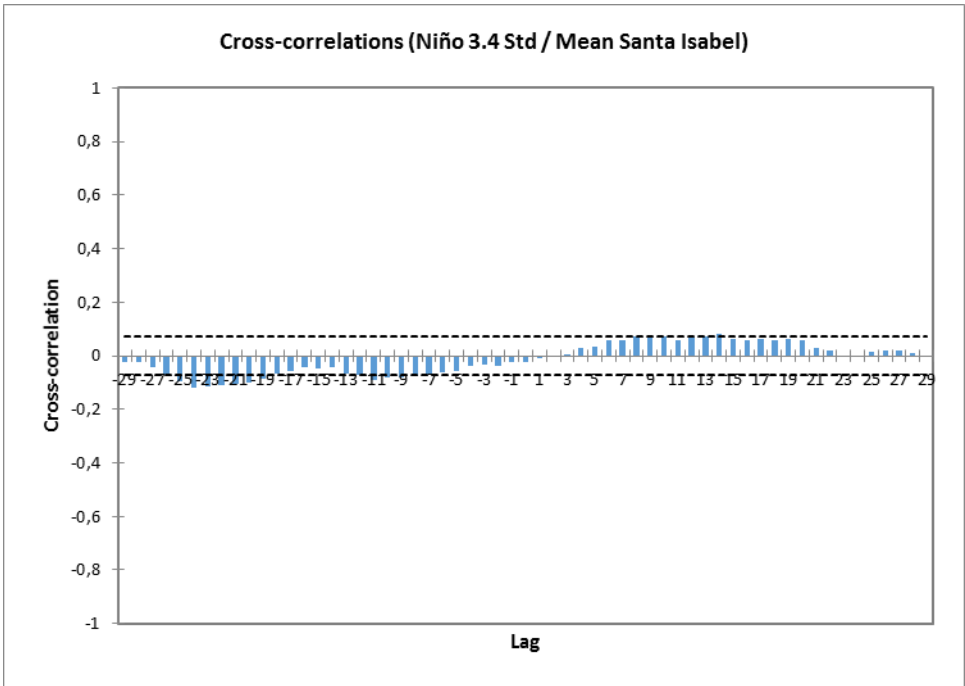


Figure 52 Cross-correlation between the El Niño 3.4 index and mean precipitation values at Santa Isabel station

As for the correlation between the El Niño 3.4 index and the maximum values of precipitation, the same thing may be said about the cycle: the period between the maximum peaks is that of 11 to 13 months. The absolute maximum correlation (0.3335), though, occurs within 3 lags of the El Niño event. That is, the maximum precipitation values experience a rise 3 months after the El Niño maximum value is registered.

For this particular meteorological station, Real del Castillo (Figure 53), the peak correlation values vary from 0.2078 to 0.3335. For all the other stations, these results are similar: the maximum peaks vary between 0.18 to 0.35.

For all other cross-correlation graphs, see Annex 3.

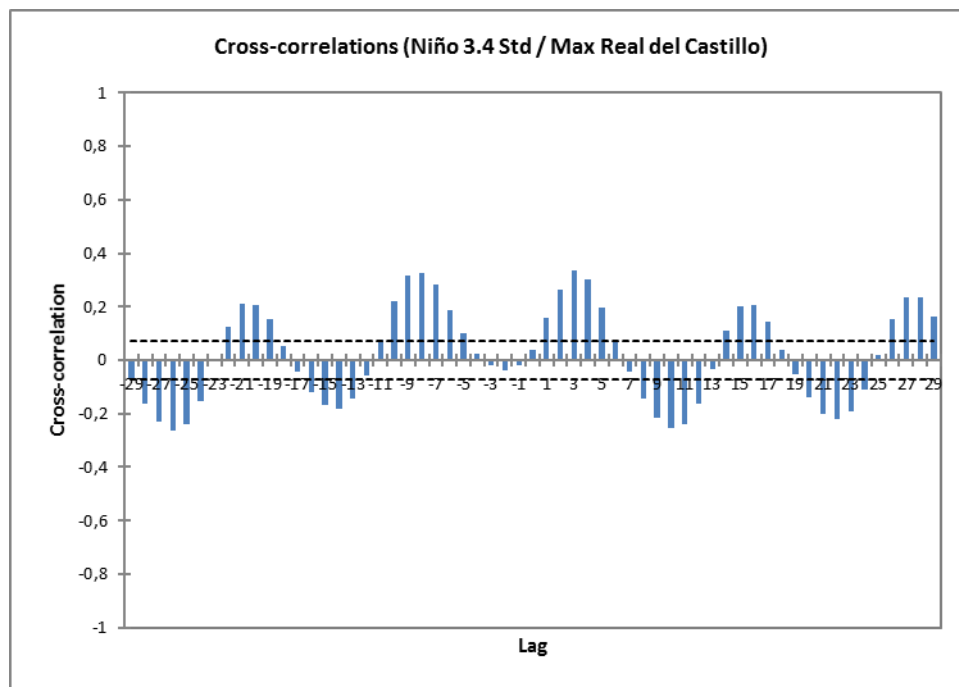


Figure 53 Cross-correlation between the El Niño 3.4 index and maximum precipitation values at Real del Castillo station

Yet again, the only exception to this rule is the Santa Isabel station (Figure 54): no significant correlation was found between the El Niño 3 index and the maximum precipitation values.

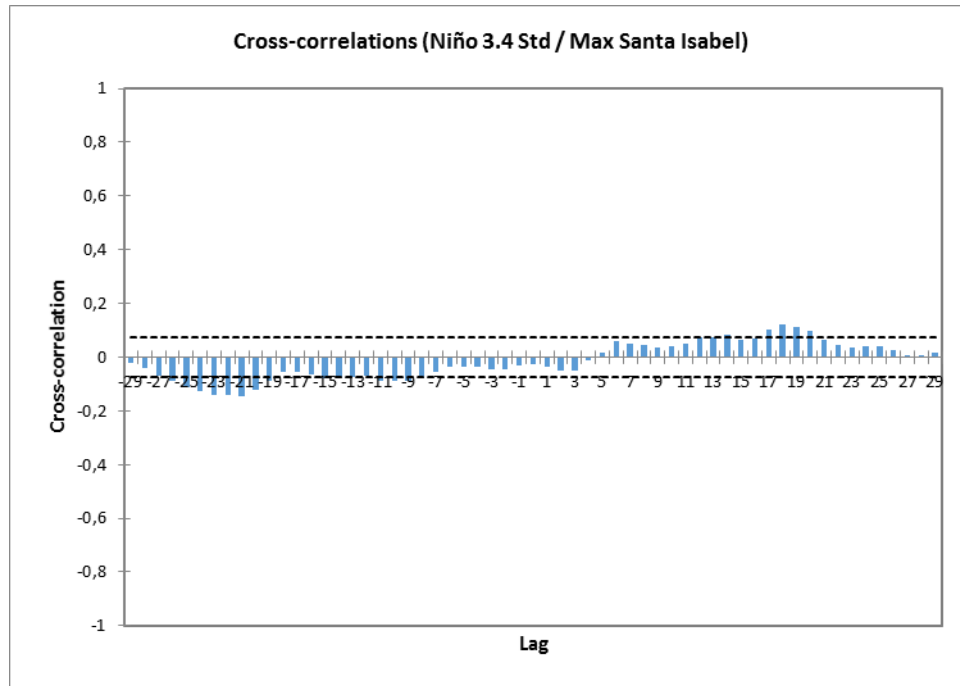


Figure 54 Cross-correlation between the El Niño 3.4 index and maximum precipitation values at Santa Isabel station

El Niño 4

In the case of El Niño 4 index the cycle can still be observed, though not as clearly as with previous El Niño indexes. Still, the 11 or 12 month periodicity is registered. For example, see Figure 55.

The correlation peaks vary between 0.10 and 0.24 and in some cases (as the observations move further to the left and right of the point 0) can come as low as 0.07. Moreover, the absolute maximum peaks appear with either -24 or -5 lag (that is, 24 or 5 months prior to the el Niño event the mean precipitation experiences its maximum peak).

For that reason, it is difficult to formulate a generalized conclusion for the El Niño 4 index correlation with mean precipitation registered in the seventeen stations.

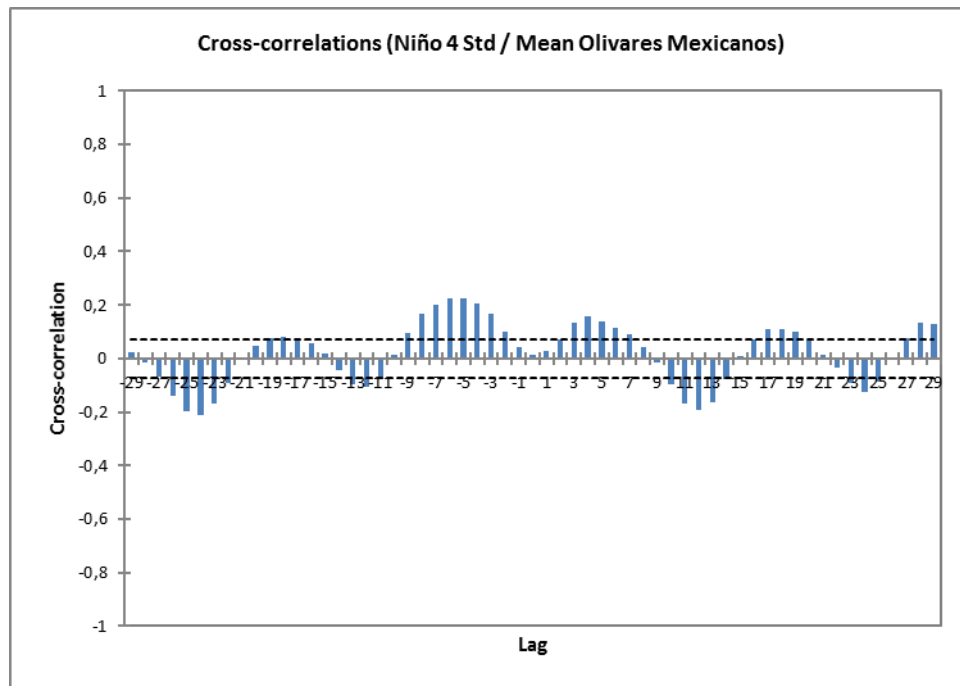


Figure 55 Cross-correlation between the El Niño 4 index and mean precipitation values at Olivares Mexicanos station

Again, the Santa Isabel station presents an exception: no significant correlation was found between the El Niño 4 index and the mean precipitation in Santa Isabel station (Figure 56)

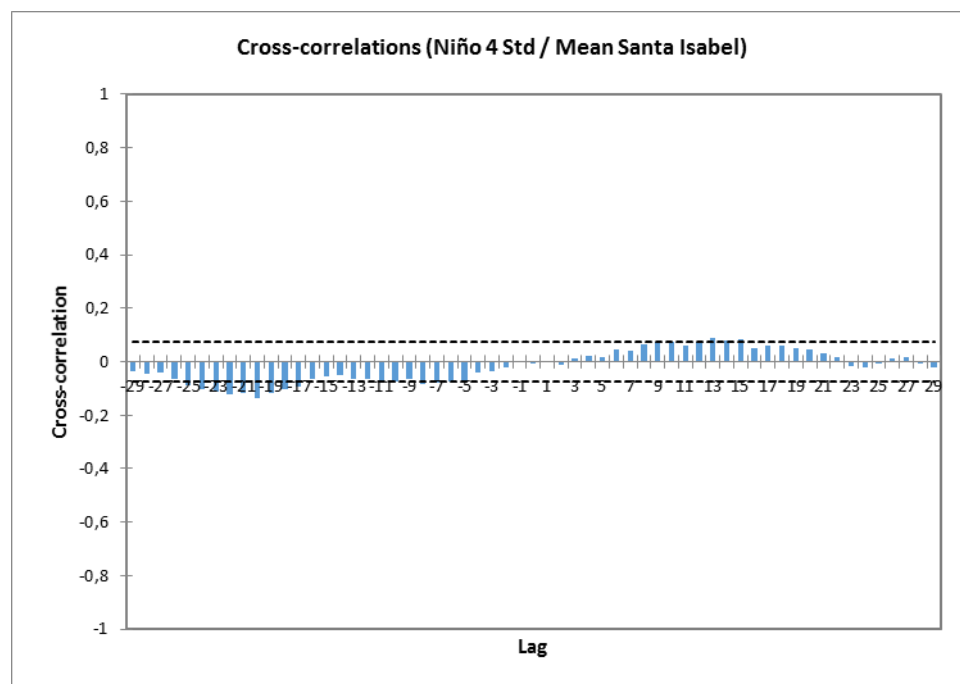


Figure 56 Cross-correlation between the El Niño 4 index and mean precipitation values at Santa Isabel station

For the maximum values of precipitation and their correlation with the El Niño 4 index, the same may be said as in case of the mean precipitation values: the periodicity of 11 to 12 months is present, but the correlation peaks are low (as low as 0.07). For an example, see Figure 57.

In this case, it is also difficult to formulate a generalized conclusion for the El Niño 4 index correlation with maximum precipitation registered in the seventeen stations.

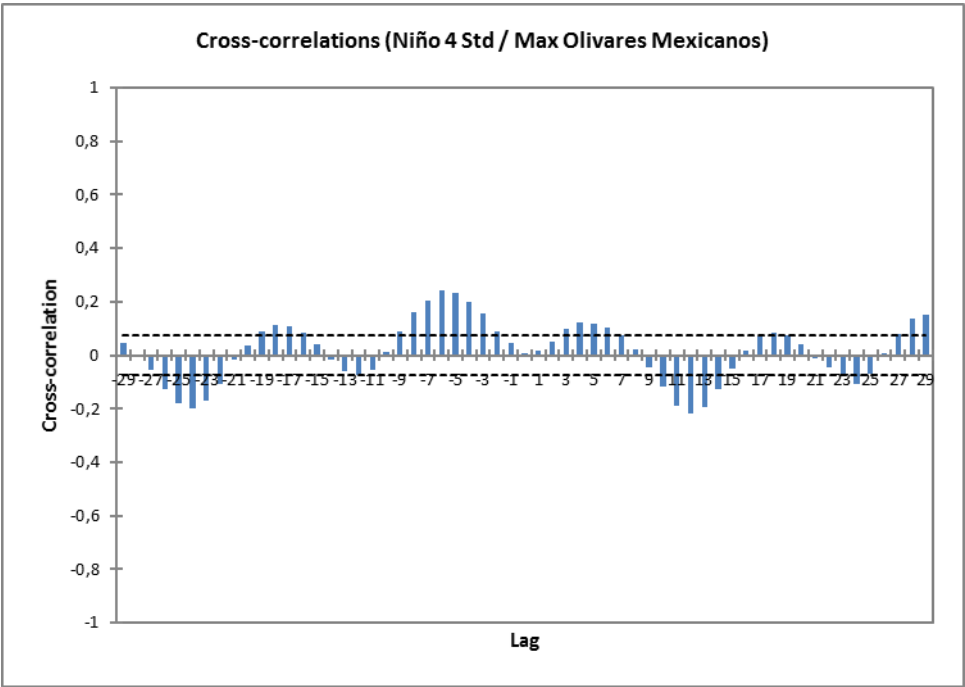


Figure 57 Cross-correlation between the El Niño 4 index and maximum precipitation values at Olivares Mexicanos station

Again, the Santa Isabel station presents an exception: no significant correlation was found between the El Niño 4 index and the maximum precipitation in Santa Isabel Station (Figure 58).

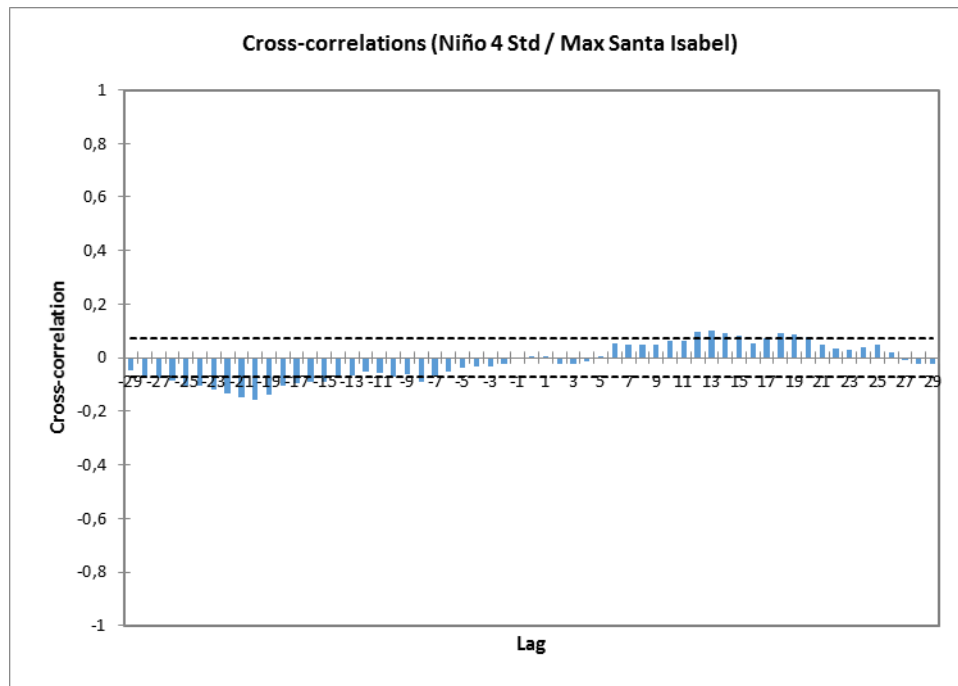


Figure 58 Cross-correlation between the El Niño 4 index and maximum precipitation values at Santa Isabel station

NP

As can be clearly seen, the correlation between the NP index and the mean precipitation values is cyclical. The period between the maximum peaks of correlation is that of 11 to 13 months. The absolute maximum correlation (-0.4619) occurs within 1 lag before the NP event. That is, the mean precipitation experiences a clear fall in its value 1 month before the maximum NP index value.

For this particular meteorological station, Maneadero (Figure 59), the peak correlation values vary from -0.3949 to -0.4619. For all the other stations, these results are similar: the maximum peaks vary between -0.39 to -0.46 (with the exception of Héroes de la Independencia station, where the peaks are as low as -0.11).

For all other cross-correlation graphs, see Annex 3.

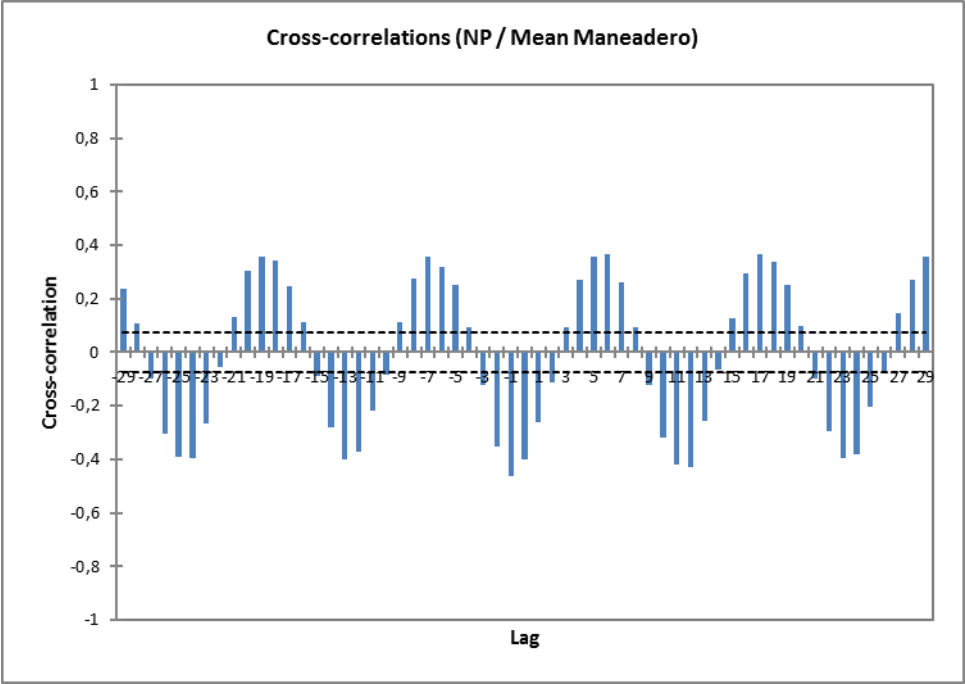


Figure 59 Cross-correlation between the NP index and mean precipitation values at Maneadero station

Santa Isabel station (Figure 60) is, again, an exception: no significant correlation was found between the NP index and the mean precipitation values.

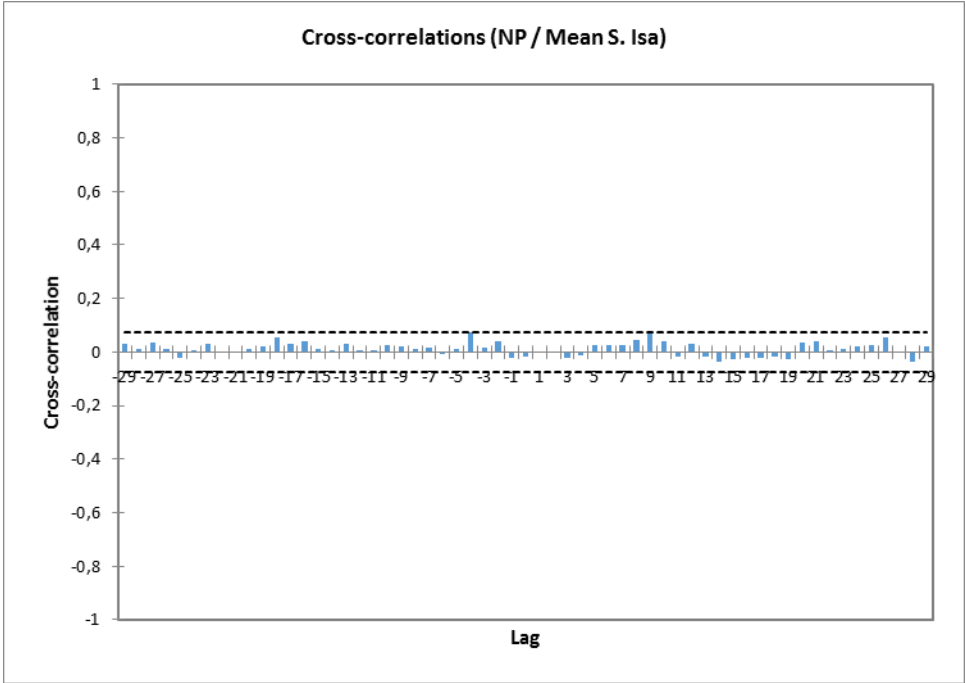


Figure 60 Cross-correlation between the NP index and mean precipitation values at Santa Isabel station

As for the correlation between the NP index and the maximum values of precipitation, the same thing may be said about the cycle: the period between the maximum peaks is that of 12 to 13 months. The absolute maximum correlation (-0.4518) occurs within -1 lags of the El Niño event. That is, the maximum precipitation values experience a fall 1 month before the NP event.

For this particular meteorological station, Maneadero (Figure 61), the peak correlation values vary from -0.3767 to -0.4518. For all the other stations, these results are similar: the maximum peaks vary between -0.3 to -0.47 (with the exception of Héroes de la Independencia station, where the peaks are as low as -0.2).

For all other cross-correlation graphs, see Annex 3.

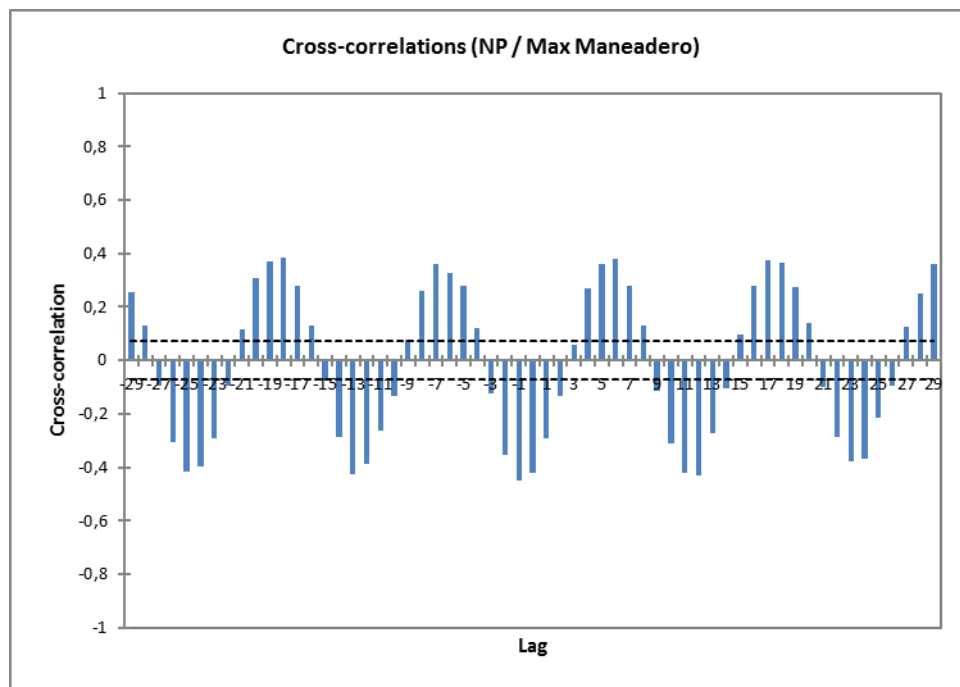


Figure 61 Cross-correlation between the NP index and maximum precipitation values at Maneadero station

Yet again, the only exception to this rule is the Santa Isabel station (Figure 62): no significant correlation was found between the El Niño 3 index and the maximum precipitation values.

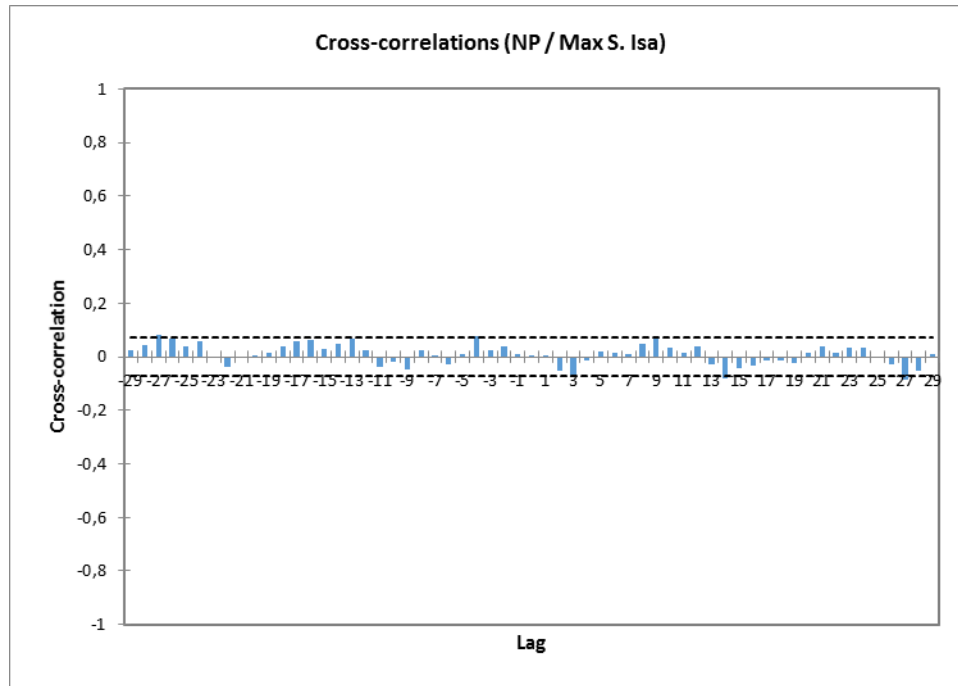


Figure 62 Cross-correlation between the NP index and maximum precipitation values at Santa Isabel station

Once the cross-correlation test was executed for each of the meteorological stations, a general picture for the catchment area was needed. For that the mean values of the maximum and mean values of the seventeen meteorological stations were calculated and the cross-correlation test was run between those values and the El Niño and NP indexes.

In general, the correlation values between the meteorological stations and the indexes are cyclical with good correlation values with the exception of Santa Isabel station where no periodicity is observed and no significant correlation value found. In this particular case, it may be due to the fact that the area where this station is located has a specific micro climate.

El Niño 1+2 for the whole area

For both cases (mean of all the mean values of the seventeen stations and mean of all the maximum values of the seventeen stations) the correlation is maintained (Figure 63 and Figure 64, respectively). That is, the periodicity is that of 12 months and for the mean of all the mean values the maximum peak (0.4984) occurs 1 month after the El Niño event and for the mean of all the maximum values the maximum peak (0.5118) occurs 2 months after the maximum values of the El Niño are registered.

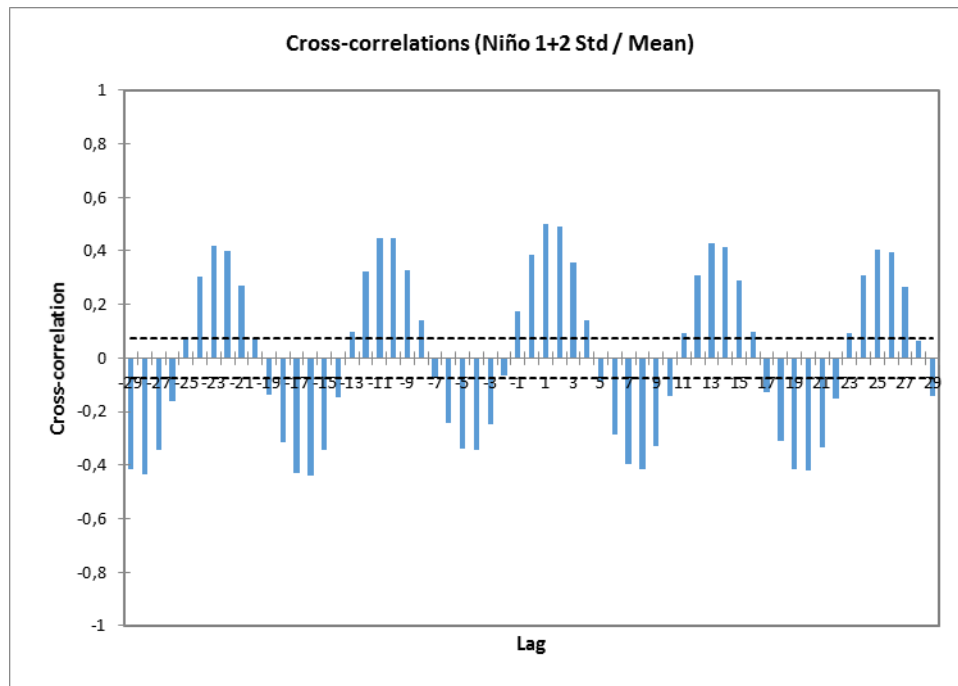


Figure 63 Cross-correlation between the El Niño 1+2 index and mean precipitation values in the catchment area

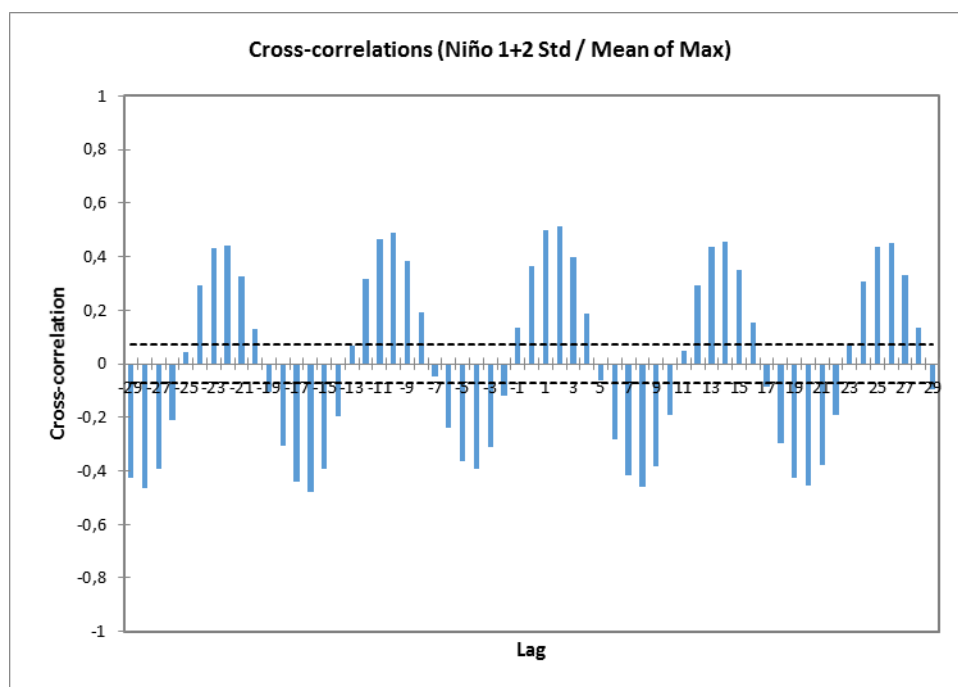


Figure 64 Cross-correlation between the El Niño 1+2 index and maximum precipitation values in the catchment area

El Niño 3 for the whole area

For both cases (mean of all the mean values of the seventeen stations and mean of all the maximum values of the seventeen stations) the correlation is maintained (Figure 65 and Figure 66, respectively). That is, the periodicity is that of 12 months and for the mean of all the mean

values the maximum peak (0.4489) occurs 2 months after the El Niño event and for the mean of all the maximum values the maximum peak (0.4479) occurs 3 months after the maximum cyclic values of the El Niño index.

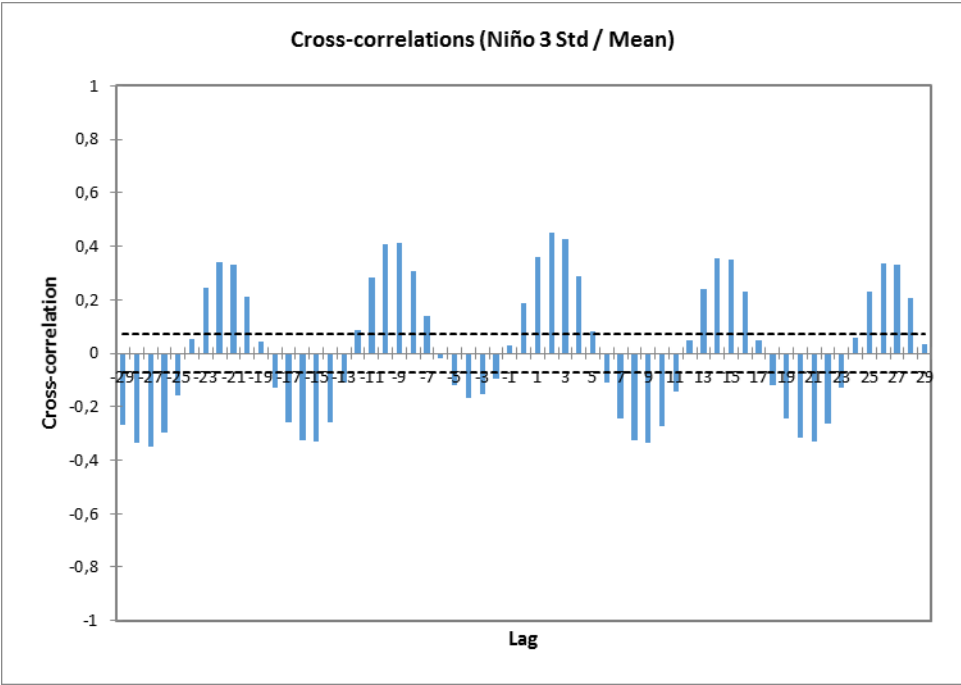


Figure 65 Cross-correlation between the El Niño 3 index and mean precipitation values in the catchment area

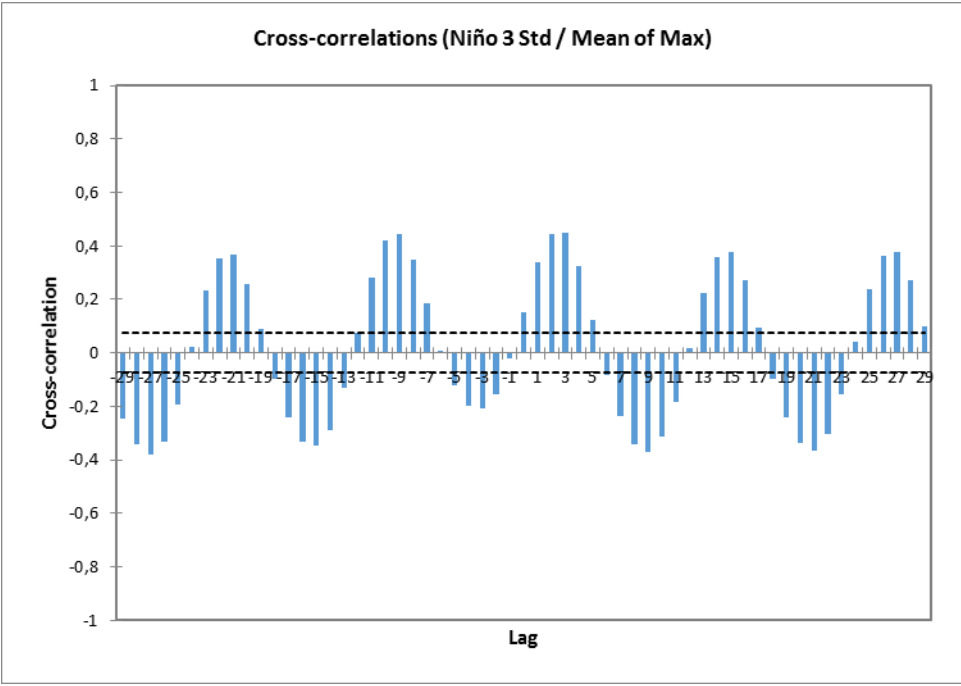


Figure 66 Cross-correlation between the El Niño 3 index and maximum precipitation values in the catchment area

El Niño 3.4 for the whole area

For both cases (mean of all the mean values of the seventeen stations and mean of all the maximum values of the seventeen stations) the correlation is maintained (Figure 67 and Figure 68, respectively). That is, the periodicity is that of 12 months and for the mean of all the mean values the maximum peak (0.3278) occurs 3 months after the El Niño event and for the mean of all the maximum values the maximum peak (0.3199) occurs 3 months after the maximum value of the El Niño index is registered.

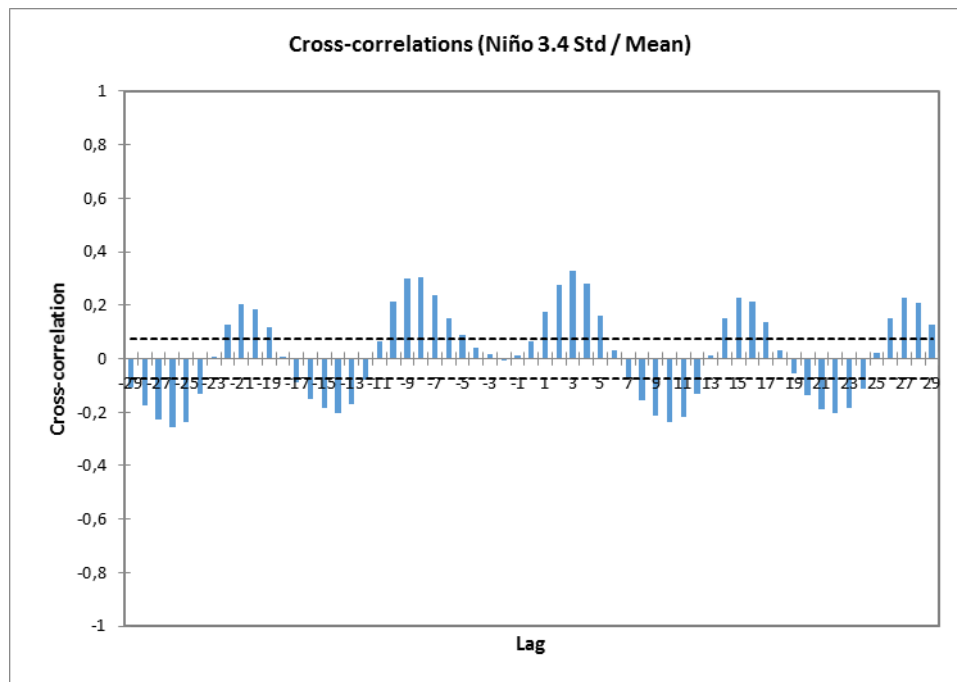


Figure 67 Cross-correlation between the El Niño 3.4 index and mean precipitation values in the catchment area

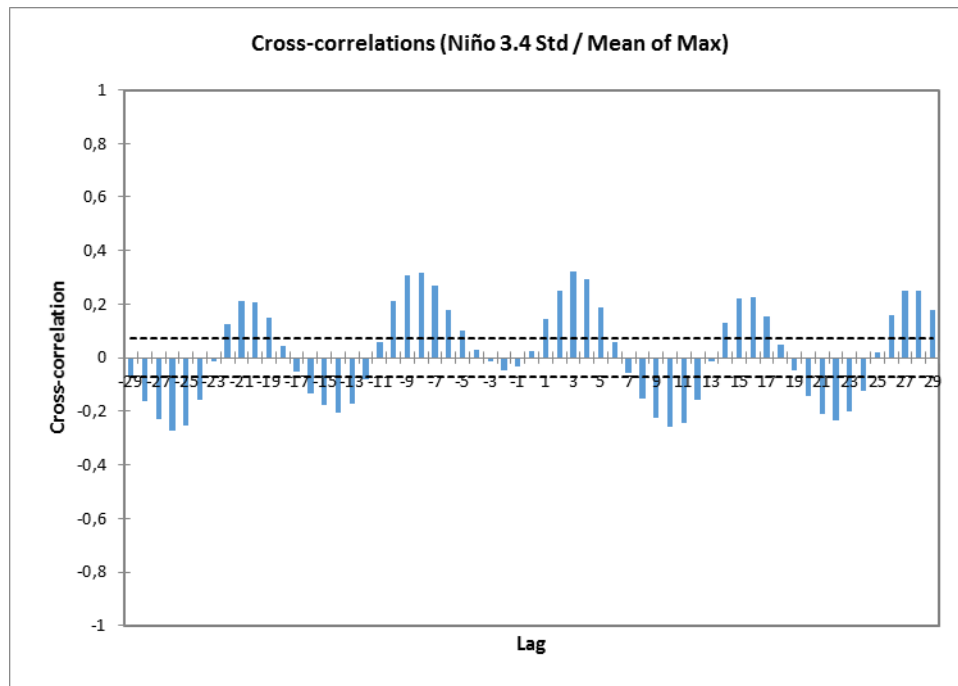


Figure 68 Cross-correlation between the El Niño 3.4 index and maximum precipitation values in the catchment area

El Niño 4 for the whole area

For these two cases, the correlation maintains its parameters and the 12 months periodicity (Figure 69 and Figure 70). And, as in the majority of the meteorological stations on their own, the absolute maximum correlation peak (0.2046 for the mean of the mean values and 0.2173 mean of maximum values) occurs 5 months prior to the maximum cyclic value of the El Niño index.

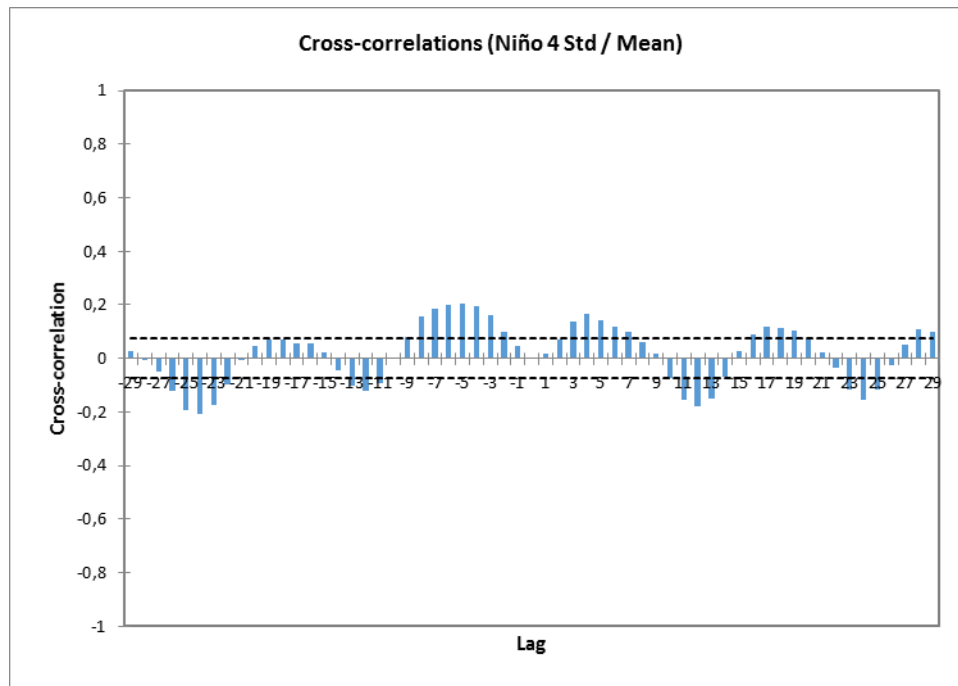


Figure 69 Cross-correlation between the El Niño 4 index and mean precipitation values in the catchment area

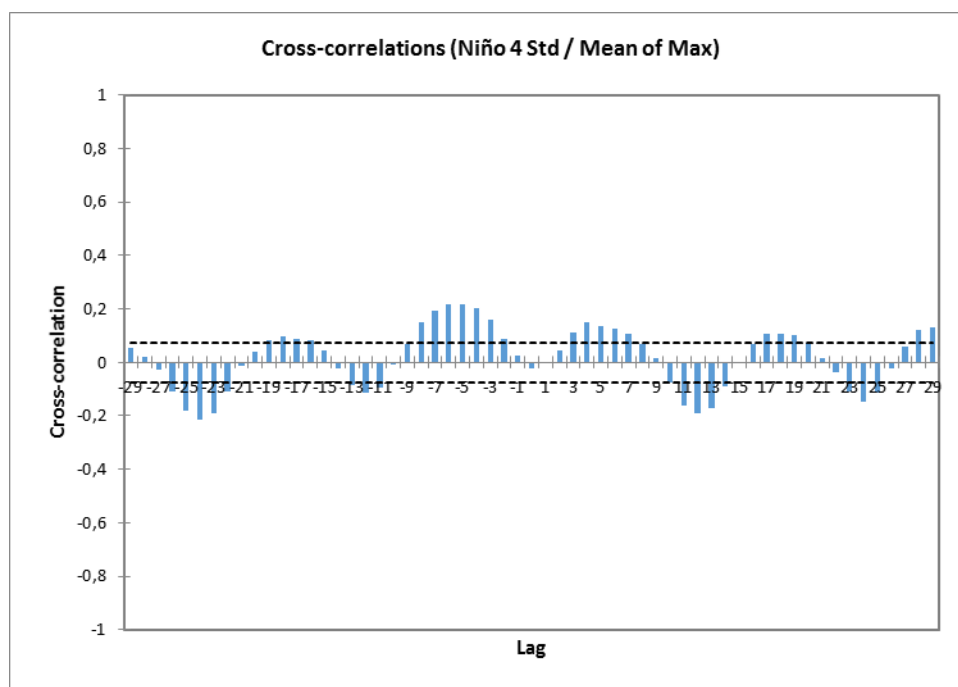


Figure 70 Cross-correlation between the El Niño 4 index and maximum precipitation values in the catchment area

NP for the whole area

For both cases (mean of all the mean values of the seventeen stations and mean of all the maximum values of the seventeen stations) the correlation is maintained (Figure 71 and Figure 72, respectively). That is, the periodicity is that of 12 months and for the mean of all the mean

values the maximum peak (-0.4504) occurs 1 month prior to the NP phenomenon and for the mean of all the maximum values the maximum peak (-0.4543) also occurs 1 month prior to maximum value of the NP index.

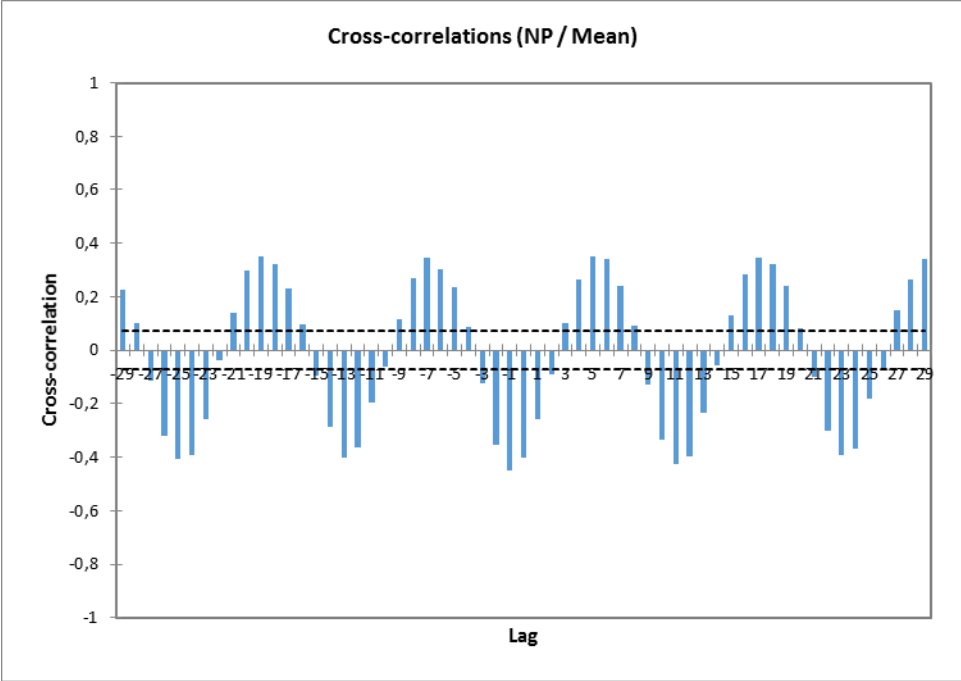


Figure 71 Cross-correlation between the NP index and mean precipitation values in the catchment area

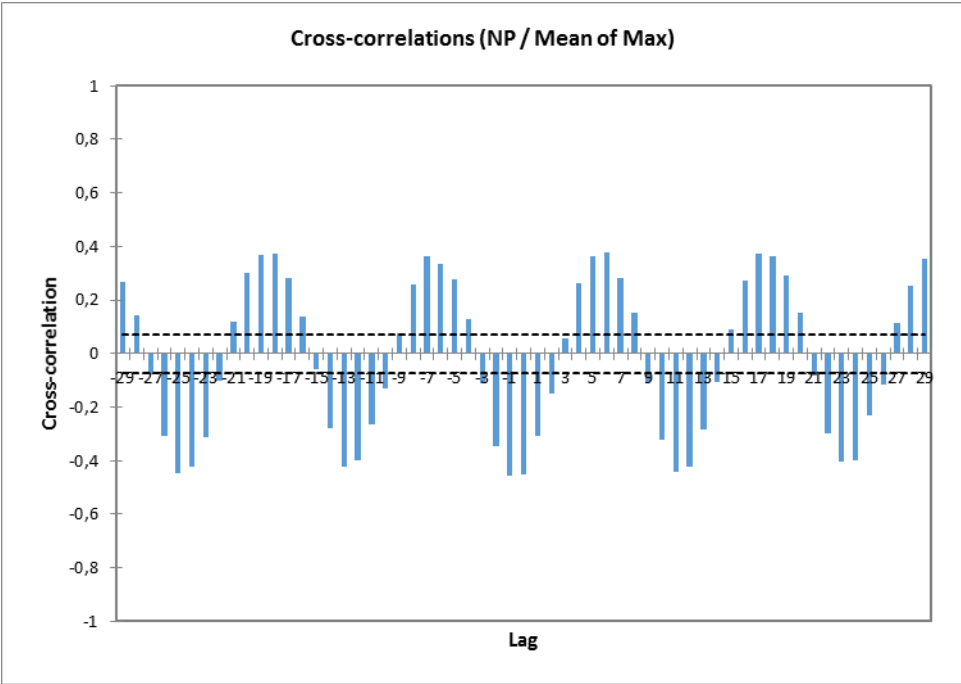


Figure 72 Cross-correlation between the NP index and maximum precipitation values in the catchment area

When natural phenomena are considered, the correlation of 0.5 is considered a high correlation. In these particular cases, the 0.5 correlation is reached and in some cases surpasses it.

An important point should be taken into the account and that is the fact that the only parameter taken into consideration were the climate indexes. Precipitation depends on a lot of other factors, such as temperature, humidity, wind direction, etc. that were not available at the moment of the research for this thesis.

With all that in mind, it still may be said that the precipitation in this catchment area is correlated with the El Niño phenomenon. The relation is especially good with the El Niño 1+2 index, measured near the Peruvian coast. As other regions where the El Niño phenomenon are further away from the coast (the area where El Niño 4 index is measured is closer to the Papua New Guinea coast than to the western South American coast), the correlation values drop in value. Still, the periodicity is clear and a certain significant correlation exists between the precipitation and the indexes.

Summary and conclusions

This thesis aimed to characterize the rainfall events of the catchment area in Ensenada, Baja California, México. The rainfall records were obtained from 17 stations around the catchment area and the city of Ensenada, covering a time span of nearly 60 years. Those records, though, had significant gaps with no data, so the first step was to reconstruct the time series of those stations.

To do so, various mathematical and statistical tools were used, such as multiple regression method for data restoration, Weibull distribution for mean and extreme (using the maximum annual values) climate characterization, Mann-Kendall trend test for trend identification and cross-correlation test for correlation identification between the precipitation and climate indexes.

An interesting finding was that the multiple regression method used for data restoration holds up well: the comparative statistics don't vary much and, when comparing the parameters in Weibull distributions and the precipitation given a non-exceedance probability for the original and restored data don't vary a lot either.

Though the results of the data restoration are satisfactory, it should be noted that the multiple regression method for this kind of restoration is very time consuming, as various formulas have to be contrasted with available data at each point, the best relation (r^2) has to be taken into account and the Fisher test should also be considered.

Regarding the extreme and mean climate, the Weibull parameters (A, B and C) have been established, allowing the calculation of the precipitation values related to a given return period and to a given non-exceedance probability. From the results, it can be seen that in order to get values of precipitation of more than 100mm one should consider return periods of over 300 years. This result, however, should be taken with caution as the predictions made from 60 years of available data for long return periods is somehow risky, since the uncertainty of these calculations increases with the return period.

Considering the overall precipitation data, that is, all the data available (including "dry days"), it was established that generally 90% of the time the precipitation is that of 0mm. Considering only the effective precipitation (i.e., precipitation exceeding the 0mm), the precipitation values of 100mm or over correspond to 0.99 or 0.999 probability of non-exceedance.

These results are in accordance to the fact that Ensenada is an arid zone and does not experience excessive rain fall and explains, in part, the draught conditions experienced by the Baja California State.

In regard to establishing an existence of a seasonal or monthly trends, for which Mann-Kendall trend test was used, the results showed that for most stations, there are no monthly nor seasonal increasing or decreasing trends, with the exception of El Ciprés station's where data show a negative trend which translates to less precipitation in spring and summer (seasonally) and in May, July and August (monthly); Ojos Negros station shows a negative trend in autumn (seasonally) and Punta Banda, San Rafael, Maneadero and Sierra de Juárez stations also experience less precipitation in May, June, July and August. On the other hand, Real del Castillo

and San Rafael stations experience a positive trend which translates to more precipitation in winter. Eleven out of the seventeen stations experience an increase in precipitation in February.

From this, the summers and considered hotter months are becoming dryer and Februaries, one of the rainiest months, are becoming wetter. For a better and a more precise conclusion, more data needs to be analysed.

A more interesting finding of this thesis was the correlation between the precipitation and the climate indexes, particularly the El Niño index. All the meteorological stations, with the exception of Santa Isabel station, had a significant correlation values for the NP, El Niño 1+2, El Niño 3, El Niño 3.4 and El Niño 4 indexes.

A particular interesting point is the correlation between the precipitation and the El Niño 1+2 index: the correlation values, in a number of stations and in the general picture, are over 0.5 value that is considered high in case of natural phenomena. Also, it was found that the maximum correlation between the precipitation and the El Niño 1+2 index occurs 1 or 2 months after the maximum values of this phenomenon. So, the maximum precipitation is generally expected one month after the maximum values of El Niño 1+2 index.

Though these findings are statistically significant, it should be noted that other parameters that influence rainfall, such as temperature, humidity or atmospheric pressure, were not considered. Yet, the correlation is significant and in order to obtain a more accurate prediction relating the precipitation and El Niño index a more thorough and complex study is needed.

Precipitation constitutes an important part of the hydrologic cycle, since it produces the planet's renewable water resources. And in order to ensure the correct water management, predictions of the expected precipitation should form part of the assessments.

It is necessary to manage the more and more scarce available water resources. The quantification of the mean and extreme characteristics of the rainfall in the catchment area of Ensenada may be used for the sustainable water resources management. The clear relation between El Niño 1+2 values and the related rainfall between 1 to 2 months after, may be used as a management tool for decision makers and good water use policy, so necessary for arid regions like Ensenada.

Future work

Though the results of the data restoration are satisfactory, an interesting line of future work could be comparing the results obtained in this thesis with the results that could be obtained with some rain generating software models.

On the other hand, the correlation found between the El Niño index and the mean and maximum precipitation of the area is significant, even though the only parameter contemplated in this thesis was precipitation. A compelling new study would be a study other atmospheric parameters, such as temperature, humidity, temperature at the sea level of the area, etc. in order to obtain a more complete characterization of the area.

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Annex 1: Restoration equations

Olivares Mexicanos

Formula	R ²
<i>Olivares Mexicanos</i> $= -0.30017 + 0.83411\text{El Ciprés}$ $- 0.42219\text{Héroes de la Independencia}$ $+ 1.06992\text{Ojos Negros}$	0.9498
<i>Olivares Mexicanos</i> $= -0.36631 + 0.63920\text{El Ciprés}$ $+ 0.94105\text{Ojos Negros}$	0.9304
<i>Olivares Mexicanos</i> $= -0.02472 + 0.58155\text{Presa ELZ}$ $- 0.03507\text{El Álamo} + 0.22920\text{Ojos Negros}$ $+ 0.12584\text{San Carlos} + 0.15328\text{San Rafael}$ $+ 0.03229\text{Santa Isabel}$ $+ 0.09634\text{Sierra de Juárez}$	0.8433
<i>Olivares Mexicanos</i> $= -0.04652 + 0.60324\text{Presa ELZ}$ $+ 0.3398\text{El Álamo} + 0.18631\text{Ojos Negros}$ $+ 0.11543\text{San Carlos} + 0.03676\text{San Rafael}$ $+ 0.07286\text{Santo Tomás}$ $+ 0.12759\text{Sierra de Juárez}$	0.8369
<i>Olivares Mexicanos</i> $= -0.02406 + 0.49174\text{Presa ELZ}$ $+ 0.03029\text{El Álamo} + 0.12466\text{La Bocana}$ $+ 0.26896\text{Ojos Negros} + 0.10689\text{Santo Tomás}$ $+ 0.11725\text{Sierra de Juárez}$	0.7919
<i>Olivares Mexicanos</i> $= -0.00503 + 0.47671\text{Presa ELZ}$ $+ 0.03147\text{El Álamo} + 0.20143\text{Ojos Negros}$ $+ 0.13015\text{San Carlos} + 0.18406\text{Santo Tomás}$ $+ 0.07681\text{Sierra de Juárez}$	0.7886

<i>Olivares Mexicanos</i> $= 0.03972 + 0.51247$ <i>Presa ELZ</i> $+ 0.03791$ <i>El Álamo</i> $+ 0.14128$ <i>La Bocana</i> $+ 0.32050$ <i>Ojos Negros</i> $+ 0.12268$ <i>Santo Tomás</i>	0.7875
<i>Olivares Mexicanos</i> $= 0.03369 + 0.48756$ <i>Presa ELZ</i> $+ 0.03509$ <i>El Álamo</i> $+ 0.22555$ <i>Ojos Negros</i> $+ 0.14826$ <i>San Carlos</i> $+ 0.18737$ <i>Santo Tomás</i>	0.7874
<i>Olivares Mexicanos</i> $= 0.03860 + 0.50756$ <i>Presa ELZ</i> $+ 0.14434$ <i>La Bocana</i> $+ 0.33484$ <i>Ojos Negros</i> $+ 0.14691$ <i>Santo Tomás</i>	0.7848
<i>Olivares Mexicanos</i> $= 0.01622 + 0.54935$ <i>Presa ELZ</i> $+ 0.02313$ <i>El Álamo</i> $+ 0.23731$ <i>Ojos Negros</i> $+ 0.22931$ <i>Santo Tomás</i> $+ 0.07935$ <i>Sierra de Juárez</i>	0.7813
<i>Olivares Mexicanos</i> $= 0.08509 + 0.69837$ <i>Presa ELZ</i> $+ 0.12114$ <i>El Álamo</i> $+ 0.15694$ <i>El Ciprés</i> $+ 0.14069$ <i>Santo Tomás</i>	0.7393
<i>Olivares Mexicanos</i> $= 0.05901 + 0.57057$ <i>Presa ELZ</i> $+ 0.03935$ <i>El Álamo</i> $+ 0.25487$ <i>Ojos Negros</i> $+ 0.21786$ <i>Santo Tomás</i>	0.7330
<i>Olivares Mexicanos</i> $= 0.06734 + 0.56891$ <i>Presa ELZ</i> $+ 0.27211$ <i>Ojos Negros</i> $+ 0.23897$ <i>Santo Tomás</i>	0.7301
<i>Olivares Mexicanos</i> $= 0.03741 + 0.11145$ <i>Presa ELZ</i> $+ 0.45293$ <i>Ejido Uruapan</i> $+ 0.22680$ <i>El Ciprés</i> $+ 0.16628$ <i>Punta Banda</i> $+ 0.18380$ <i>Santo Tomás</i>	0.7227

<i>Olivares Mexicanos</i> $= 0.08376 + 0.30177\text{Presa ELZ}$ $+ 0.15366\text{Ejido Uruapan} + 0.31810\text{Maneadero}$ $+ 0.36880\text{Santo Tomás}$	0.6792
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Table 195 Restoration equations for Olivares Mexicanos station

El Álamo, Part 1

Formula	R ²
<i>El Álamo</i> $= -0.17136 + 0.24605\text{Ejido Uruapan}$ $+ 0.73165\text{Héroes de la Independencia}$ $+ 0.36518\text{Olivares Mexicanos}$	0.9726
<i>El Álamo</i> $= -0.10184 + 0.82165\text{Héroes de la Independencia}$ $+ 0.55845\text{Olivares Mexicanos}$	0.9653

Table 196 Restoration equations for El Álamo station, part one

Ojos Negros

Formula	R ²
<i>Ojos Negros</i> $= 0.00336 + 0.00365\text{Presa ELZ}$ $+ 0.01642\text{El Álamo} + 0.07133\text{El Ciprés}$ $+ 0.15960\text{Olivares Mexicanos}$ $- 0.22891\text{Punta Banda}$ $+ 0.42254\text{Real del Castillo} + 0.38442\text{San Carlos}$	0.8543
<i>Ojos Negros</i> $= 0.01603 + 0.04131\text{Presa ELZ}$ $+ 0.02644\text{El Álamo}$ $+ 0.18429\text{Olivares Mexicanos}$ $- 0.21969\text{Punta Banda}$ $+ 0.40897\text{Real del Castillo} + 0.35952\text{San Carlos}$	0.8367
<i>Ojos Negros</i> $= 0.03505 + 0.20880\text{Presa ELZ}$ $+ 0.12819\text{El Álamo} + 0.08354\text{El Ciprés}$ $+ 0.10286\text{Maneadero}$ $+ 0.09176\text{Olivares Mexicanos}$ $+ 0.22532\text{San Carlos}$	0.8128

$\begin{aligned} \text{Ojos Negros} = & 0.02783 + 0.11019\text{Presa ELZ} \\ & + 0.10422\text{El Álamo} + 0.08621\text{El Ciprés} \\ & + 0.14442\text{Olivares Mexicanos} \\ & + 0.36017\text{San Carlos} \end{aligned}$	0.8090
$\begin{aligned} \text{Ojos Negros} = & 0.03396 + 0.23449\text{Presa ELZ} \\ & + 0.12247\text{El Álamo} + 0.13104\text{Maneadero} \\ & + 0.10781\text{Olivares Mexicanos} \\ & + 0.21911\text{San Carlos} \end{aligned}$	0.8011
$\begin{aligned} \text{Ojos Negros} = & 0.04537 + 0.21054\text{Presa ELZ} \\ & + 0.08053\text{El Ciprés} + 0.14354\text{Maneadero} \\ & + 0.12502\text{Olivares Mexicanos} \\ & + 0.28731\text{San Carlos} \end{aligned}$	0.7978
$\begin{aligned} \text{Ojos Negros} = & 0.04911 + 0.16660\text{Presa ELZ} \\ & + 0.19333\text{Olivares Mexicanos} \\ & - 0.04880\text{Punta Banda} + 0.43924\text{San Carlos} \end{aligned}$	0.7900

Table 197 Restoration equations for Ojos Negros station

San Carlos

Formula	R ²
$\begin{aligned} \text{San Carlos} = & 0.07069 + 0.45214\text{Presa ELZ} \\ & + 0.13859\text{Ejido Uruapan} + 0.08038\text{El Álamo} \\ & - 0.18214\text{La Bocana} + 0.42763\text{Maneadero} \\ & + 0.21777\text{Ojos Negros} \end{aligned}$	0.8929
$\begin{aligned} \text{San Carlos} = & 0.08955 + 0.49542\text{Presa ELZ} \\ & - 0.11928\text{La Bocana} + 0.47549\text{Maneadero} \\ & + 0.31311\text{Ojos Negros} \end{aligned}$	0.8862
$\begin{aligned} \text{San Carlos} = & 0.05010 + 0.59307\text{Presa ELZ} \\ & + 0.23899\text{Ejido Uruapan} + 0.06771\text{El Álamo} \\ & + 0.10789\text{El Ciprés} - 0.06700\text{La Bocana} \\ & + 0.22534\text{Ojos Negros} \end{aligned}$	0.8656

<i>San Carlos = 0.04813 + 0.43054Presa ELZ + 0.04529El Álamo + 0.03050La Bocana + 0.32449Ojos Negros + 0.03878Olivares Mexicanos + 0.22975Santo Tomás</i>	0.8634
<i>San Carlos = 0.03934 + 0.54440Presa ELZ + 0.23069Ejido Uruapan + 0.05096El Álamo + 0.10554El Ciprés + 0.23558Ojos Negros</i>	0.8619
<i>San Carlos = 0.02233 + 0.49015Presa ELZ + 0.12128Ejido Uruapan + 0.01373El Álamo + 0.26735Ojos Negros + 0.12238Olivares Mexicanos + 0.08838Real del Castillo</i>	0.8555
<i>San Carlos = 0.02614 + 0.51221Presa ELZ + 0.13542Ejido Uruapan + 0.01950El Álamo + 0.30935Ojos Negros + 0.12751Olivares Mexicanos</i>	0.8529
<i>San Carlos = 0.08040 + 0.55577Presa ELZ + 0.24410Ejido Uruapan + 0.13486El Álamo + 0.11255El Ciprés + 0.17975Punta Banda – 0.11498Santo Tomás</i>	0.8518
<i>San Carlos = 0.05251 + 0.43446Presa ELZ + 0.01164El Álamo + 0.30184Ojos Negros + 0.14437Olivares Mexicanos + 0.25692Santo Tomás</i>	0.8080
<i>San Carlos = 0.05537 + 0.43493Presa ELZ + 0.30638Ojos Negros + 0.14572Olivares Mexicanos + 0.26268Santo Tomás</i>	0,8078

Table 198 Restoration equations for San Carlos station

Ejido Uruapan

Formula	R ²
<i>Ejido Uruapan</i> $= 0.24683 + 0.90758\text{El Álamo}$ $- 0.68978\text{Héroes de la Independencia}$ $+ 0.52783\text{Santo Tomás}$	0.9321
<i>Ejido Uruapan</i> $= 0.11399 + 0.51288\text{Olivares Mexicanos}$ $+ 0.56076\text{Santo Tomás}$	0.9149

Table 199 Restoration equations for Ejido Uruapan station

La Bocana

Formula	R ²
<i>La Bocana</i> $= 0.06251 + 0.42258\text{Olivares Mexicanos}$ $+ 0.54261\text{Santo Tomás}$	0.9014

Table 200 Restoration equations for La Bocana station

Real de Castillo

Formula	R ²
<i>Real del Castillo</i> $= -0.01014 - 0.19010\text{Maneadero}$ $+ 1.16673\text{Ojos Negros} + 0.26550\text{Santo Tomás}$	0.9459
<i>Real del Castillo</i> $= -0.03924 + 1.12999\text{Ojos Negros}$ $+ 0.14700\text{Santo Tomás}$	0.9396
<i>Real del Castillo</i> $= 0.02966 + 0.00991\text{Ejido Uruapan}$ $+ 0.57345\text{Ojos Negros}$ $+ 0.13109\text{Olivares Mexicanos}$ $+ 0.23249\text{Santo Tomás}$	0.7612
<i>Real del Castillo</i> $= 0.03825 + 0.02336\text{Ejido Uruapan}$ $+ 0.65514\text{Ojos Negros} + 0.27840\text{Santo Tomás}$	0.7553

Table 201 Restoration equations for Real del Castillo station

Punta Banda, Part 1

Formula	R ²
<i>Punta Banda</i> $= -0.16131 + 0.43036\text{Presa ELZ}$ $+ 0.30399\text{Maneadero} + 0.28425\text{Santo Tomás}$	0.8588
<i>Punta Banda</i> $= -0.15541 + 0.61268\text{Presa ELZ}$ $+ 0.45098\text{Maneadero}$	0.8445

Table 202 Restoration equations for Punta Banda station, part one

Maneadero, Part 1

Formula	R ²
$\text{Maneadero} = 0.16687 + 0.13436\text{El Ciprés} \\ + 0.99889\text{Ojos Negros} + 0.22497\text{Punta Banda} \\ - 0.72418\text{Real del Castillo} \\ + 0.39990\text{Santo Tomás}$	0.8236
$\text{Maneadero} = 0.20472 + 1.06820\text{Ojos Negros} \\ + 0.27957\text{Punta Banda} \\ - 0.75786\text{Real del Castillo} \\ + 0.40223\text{Santo Tomás}$	0.8184
$\text{Maneadero} = 0.29782 + 0.34579\text{Punta Banda} \\ + 0.36817\text{Santo Tomás}$	0.7862

Table 203 Restoration equations for Maneadero station, part one

Héroes de la Independencia, Part 1

Formula	R ²
$\text{Héroes de la Independencia} \\ = 0.30711 - 1.02704\text{Ejido Uruapan} \\ + 1.08986\text{El Álamo} + 0.54104\text{Santo Tomás}$	0.8015

Table 204 Restoration equations for Héroes de la Independencia station, part one

Alamo, Part 2

Formula	R ²
$\text{El Álamo} = 0.04040 + 0.97709\text{Ejido Uruapan}$	0.8247

Table 205 Restoration equations for El Álamo station, part two

Héroes de la Independencia, Part 2

Formula	R ²
<i>Héros de la Independencia</i> = 0.30371 – 1.00496Ejido Uruapan + 1.07365El Álamo + 0.53853Santo Tomás	0.8020

Table 206 Restoration equations for Héroes de la Independencia station, part two

Punta Banda, Part 2

Formula	R ²
<i>Punta Banda</i> = –0.05178 + 0.47295Presa ELZ + 0.46206Santo Tomás	0.8534

Table 207 Restoration equations for Punta Banda station, part two

Maneadero, Part 2

Formula	R ²
<i>Maneadero</i> = 0.12805 + 1.10658Ojos Negros + 0.26962Punta Banda – 0.78300Real del Castillo + 0.40749Santo Tomás	0.8356

Table 208 Restoration equations for Maneadero station, part two

El Farito

Formula	R ²
<i>El Farito</i> = 0.07322 + 0.89045Presa ELZ – 0.11332Olivares Mexicanos – 0.15911Punta Banda	0.9270

Table 209 Restoration equations for El Farito station

El Ciprés

Formula	R ²
$\begin{aligned} \text{El Ciprés} = & 0.02261 + 1.04317\text{Presa ELZ} - 0.72042\text{El Farito} \\ & + 0.12601\text{Héroes de la Independencia} \\ & + 0.23002\text{Maneadero} - 0.22147\text{Santo Tomás} \end{aligned}$	0.7419

Table 210 Restoration equations for El Ciprés station

San Rafael

Formula	R ²
$\begin{aligned} \text{San Rafael} = & -0.06122 + 0.25443\text{El Álamo} \\ & + 0.31742\text{Heroes de Independencia} \\ & - 0.70173\text{Ojos Negros} \\ & + 0.32884\text{Oliveres Mexicanos} \\ & + 0.69729\text{Real del Castillo} \end{aligned}$	0.6942

Table 211 Restoration equations for San Rafael station

Annex 2: Kolmogorov-Smirnov GOF test

Kolmogorov-Smirnov test for Weibull distribution for original data

Station	Kolmogorov-Smirnov statistics		
	D	p-value	alpha
Presa ELZ	0.0832	0.8243	0.05
Ejido Uruapan	0.1469	0.5943	0.05
El Álamo	0.0806	0.9088	0.05
El Ciprés	0.0769	0.9960	0.05
El Farito	0.2017	0.7617	0.05
Héroes de la Independencia	0.1109	0.9135	0.05
La Bocana	0.1246	0.9258	0.05
Maneadero	0.1228	0.7469	0.05
Ojos Negros	0.1177	0.5793	0.05
Olivares Mexicanos	0.1154	0.5061	0.05
Punta Banda	0.1037	0.8980	0.05
Real del Castillo	0.1589	0.9216	0.05
San Carlos	0.0900	0.8963	0.05
San Rafael	0.1667	0.7257	0.05
Santa Isabel	0.1487	0.8914	0.05
Santo Tomás	0.0575	0.9863	0.05
Sierra de Juárez	0.1049	0.9230	0.05

Table 212 Results of Kolmogorov-Smirnov goodness of fit test for Weibull distribution for original data

Kolmogorov-Smirnov test for Weibull distribution for restored data

Station	Kolmogorov-Smirnov statistics		
	D	p-value	alpha
Presa ELZ	0.0779	0.8455	0.05
Ejido Uruapan	0.1069	0.4775	0.05
El Álamo	0.0842	0.7710	0.05
El Ciprés	0.0948	0.6422	0.05
El Farito	0.0827	0.7891	0.05
Héroe de la Independencia	0.0942	0.6406	0.05
La Bocana	0.0734	0.8912	0.05
Maneadero	0.1049	0.5015	0.05
Ojos Negros	0.0785	0.8383	0.05
Olivares Mexicanos	0.0958	0.6195	0.05
Punta Banda	0.1016	0.5432	0.05
Real del Castillo	0.0947	0.6333	0.05
San Carlos	0.0857	0.7519	0.05
San Rafael	0.1266	0.2724	0.05
Santa Isabel	0.1137	0.3987	0.05
Santo Tomás	0.0575	0.9863	0.05
Sierra de Juárez	0.0546	0.9926	0.05

Table 213 Results of Kolmogorov-Smirnov goodness of fit test for Weibull distribution for restored data

Annex 3: Cross-correlation results

El Niño 1+2

Starting from the next page, the figures representing the cross-correlation test results between the El Niño 1+2 index and the mean and maximum values of the following stations: Ejido Uruapan, El Álamo, El Ciprés, El Farito, Héroes de la Independencia, La Bocana, Maneadero, Ojos Negros, Olivares Mexicanos, Punta Banda, Real del Castillo, San Carlos, San Rafael, Santo Tomás and Sierra de Juárez.

Rainfall Characterization of the Catchment Area of Ensenada, Baja California, México

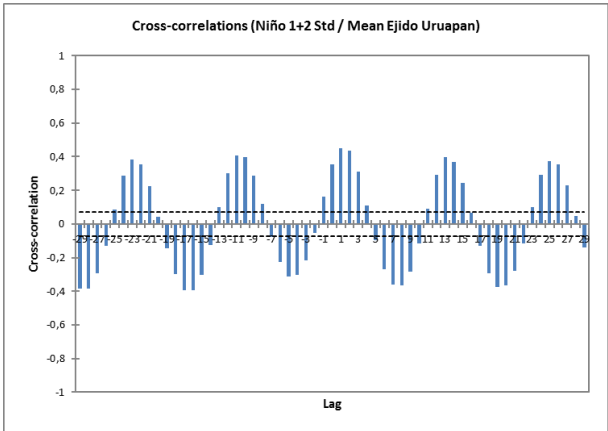


Figure 73 Cross-correlation between the El Niño 1+2 index and mean precipitation values at Ejido Uruapan station

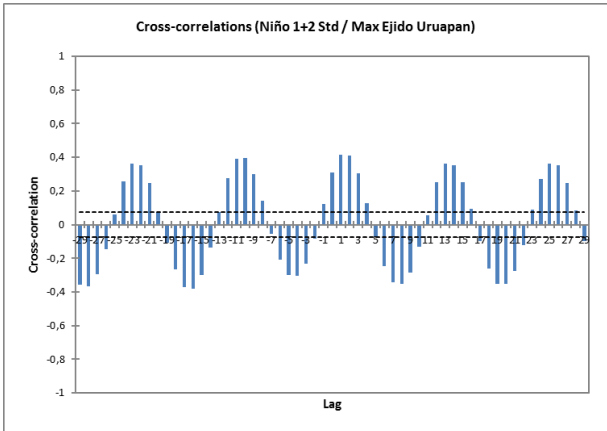


Figure 74 Cross-correlation between the El Niño 1+2 index and maximum precipitation values at Ejido Uruapan station

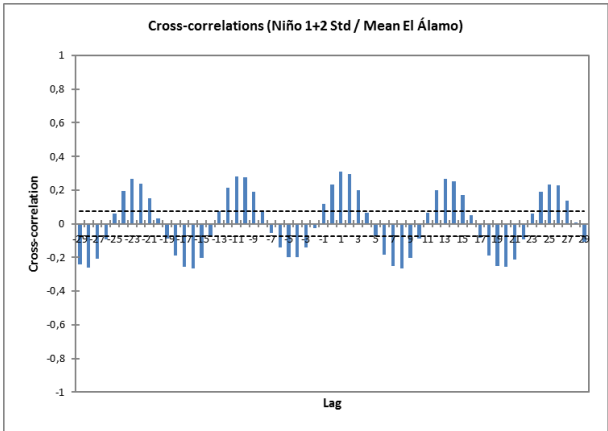


Figure 75 Cross-correlation between the El Niño 1+2 index and mean precipitation values at El Álamo station

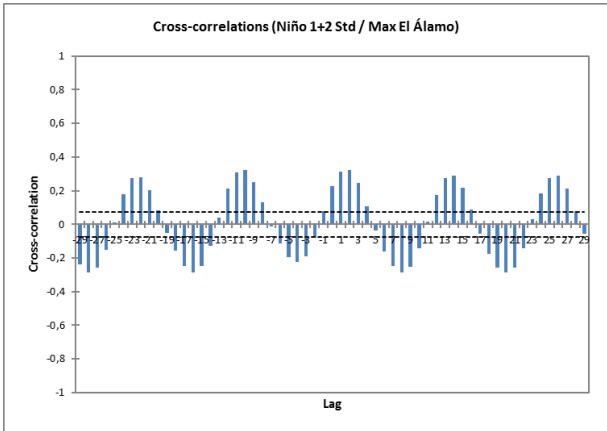


Figure 76 Cross-correlation between the El Niño 1+2 index and maximum precipitation values at El Álamo station

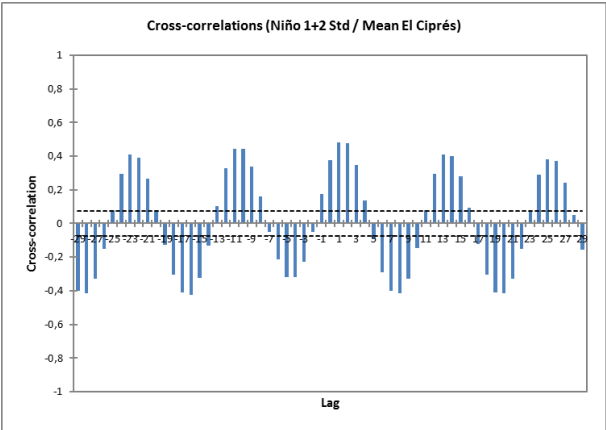


Figure 77 Cross-correlation between the El Niño 1+2 index and mean precipitation values at El Ciprés station

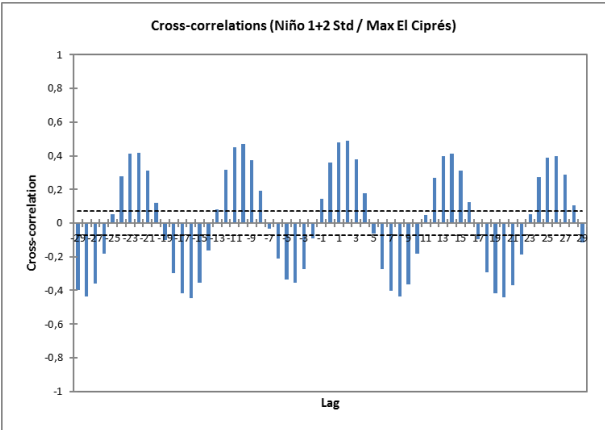


Figure 78 Cross-correlation between the El Niño 1+2 index and maximum precipitation values at El Ciprés station

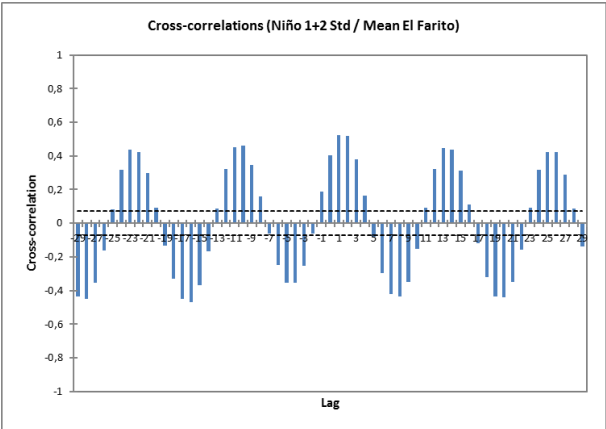


Figure 79 Cross-correlation between the El Niño 1+2 index and mean precipitation values at El Farito station

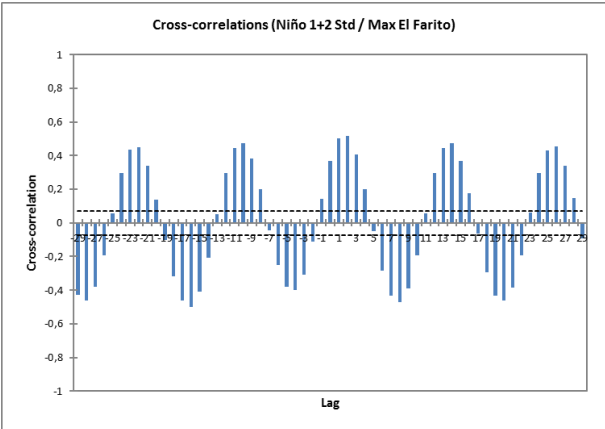


Figure 80 Cross-correlation between the El Niño 1+2 index and maximum precipitation values at El Farito station

Rainfall Characterization of the Catchment Area of Ensenada, Baja California, México

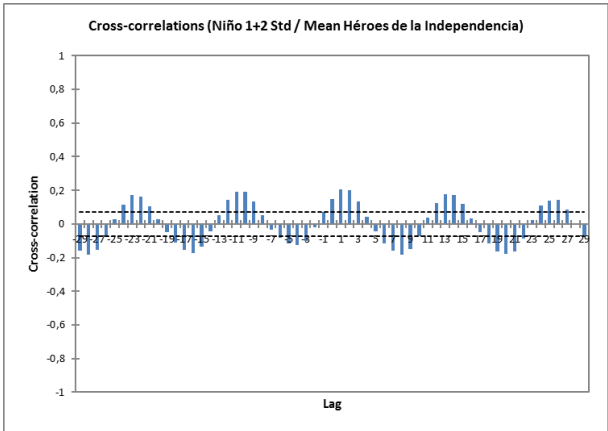


Figure 81 Cross-correlation between the El Niño 1+2 index and mean precipitation values at Héroes de la Independencia station

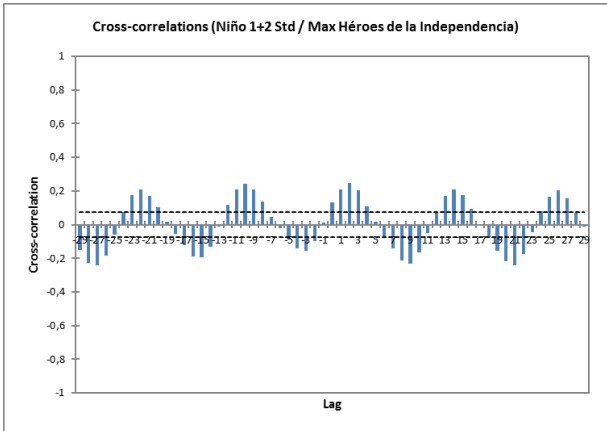


Figure 82 Cross-correlation between the El Niño 1+2 index and maximum precipitation values at Héroes de la Independencia station

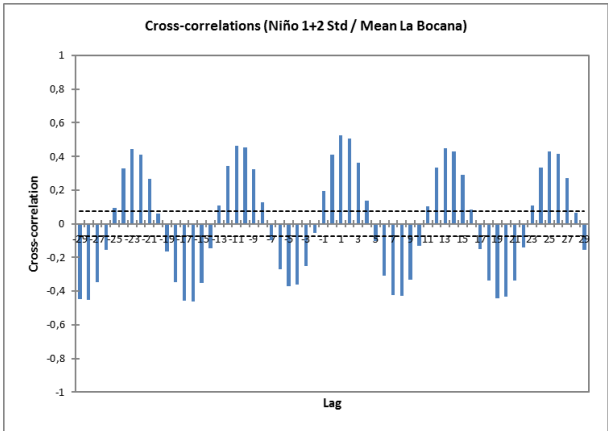


Figure 83 Cross-correlation between the El Niño 1+2 index and mean precipitation values at La Bocana station

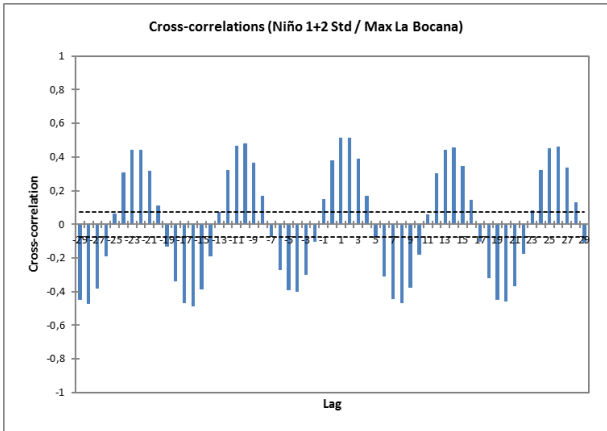


Figure 84 Cross-correlation between the El Niño 1+2 index and maximum precipitation values at La Bocana station

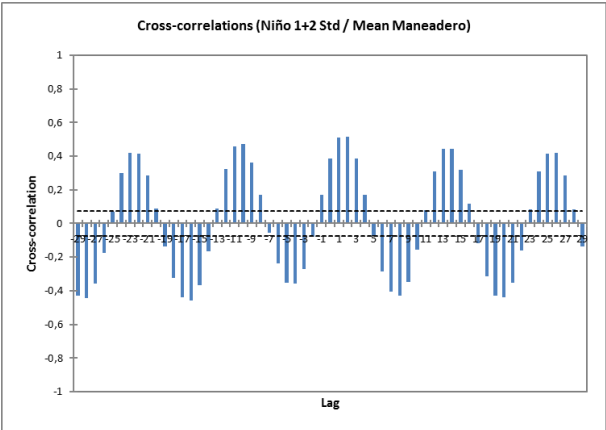


Figure 85 Cross-correlation between the El Niño 1+2 index and mean precipitation values at Maneadero station

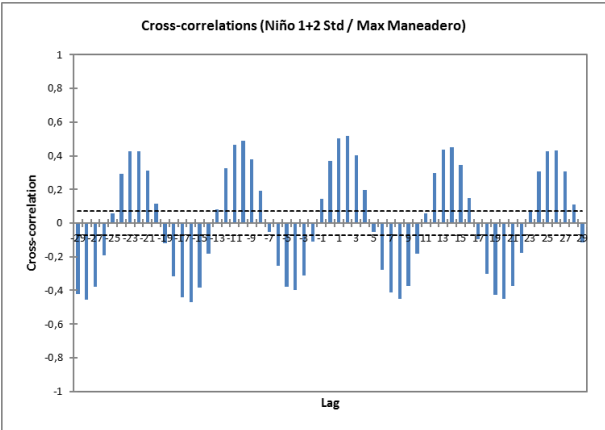


Figure 86 Cross-correlation between the El Niño 1+2 index and maximum precipitation values at Maneadero station

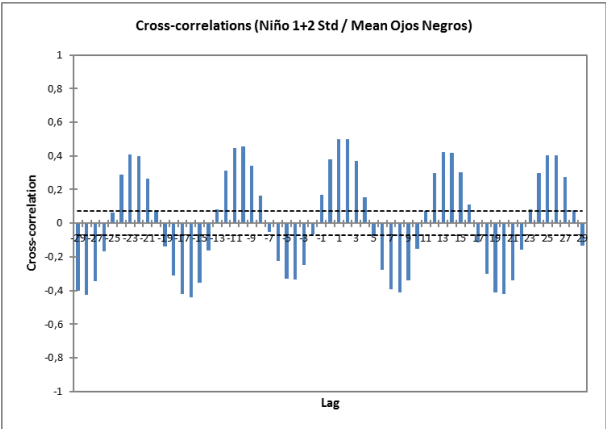


Figure 87 Cross-correlation between the El Niño 1+2 index and mean precipitation values at Ojos Negros station

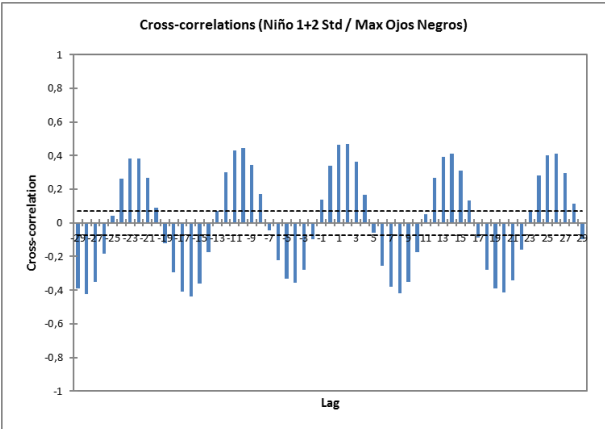


Figure 88 Cross-correlation between the El Niño 1+2 index and maximum precipitation values at Ojos Negros station

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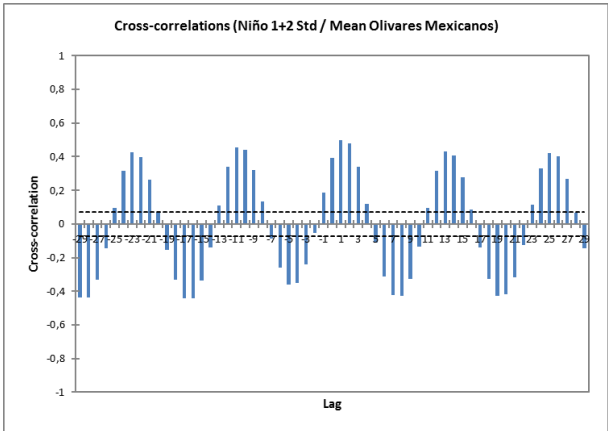


Figure 89 Cross-correlation between the El Niño 1+2 index and mean precipitation values at Olivares Mexicanos station

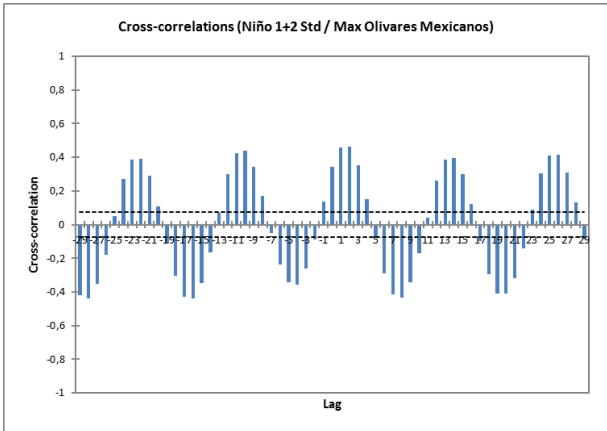


Figure 90 Cross-correlation between the El Niño 1+2 index and maximum precipitation values at Olivares Mexicanos station

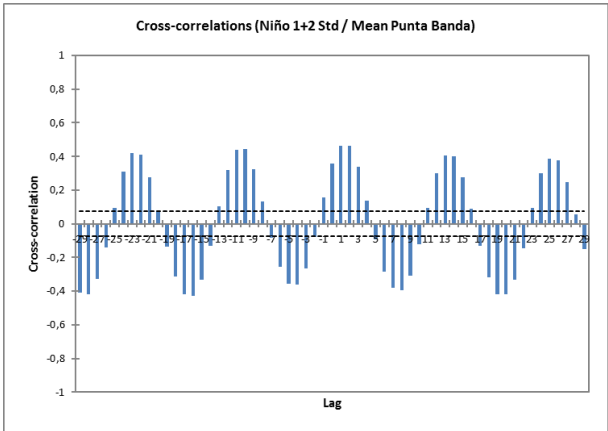


Figure 91 Cross-correlation between the El Niño 1+2 index and mean precipitation values at Punta Banda station

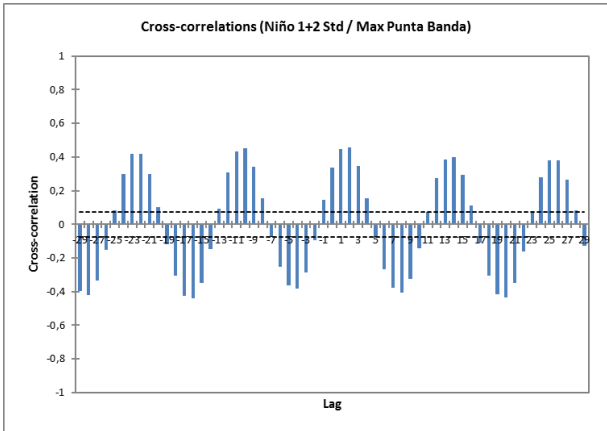


Figure 92 Cross-correlation between the El Niño 1+2 index and maximum precipitation values at Punta Banda station

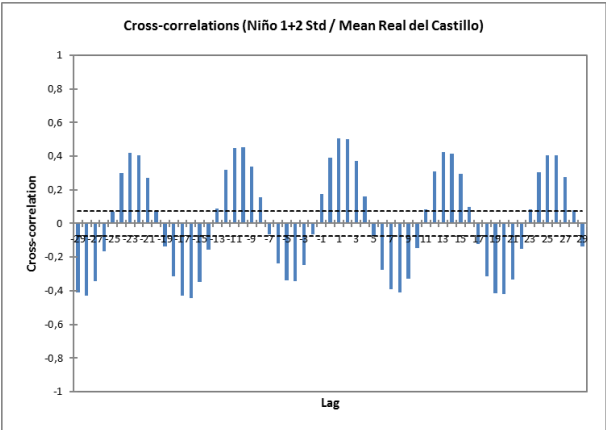


Figure 93 Cross-correlation between the El Niño 1+2 index and mean precipitation values at Real del Castillo station

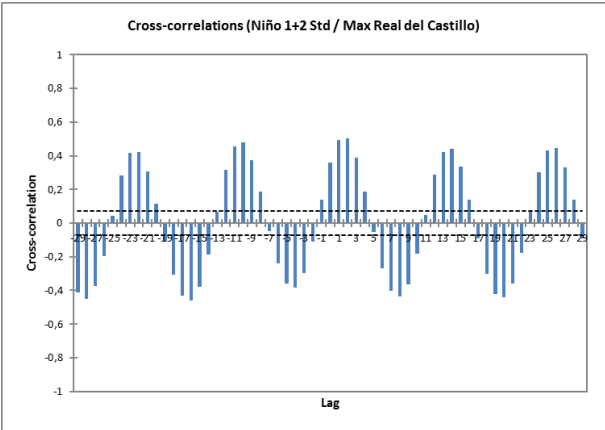


Figure 94 Cross-correlation between the El Niño 1+2 index and maximum precipitation values at Real del Castillo station

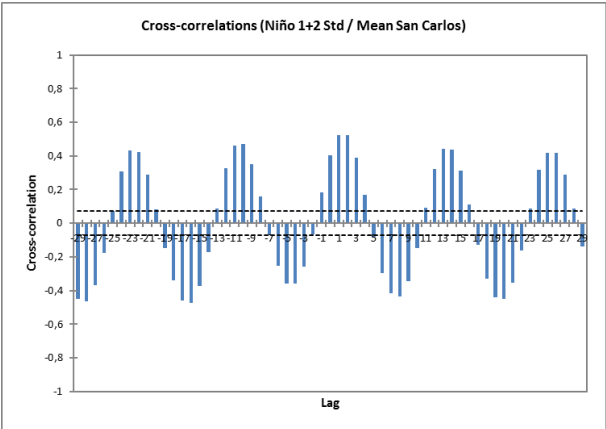


Figure 95 Cross-correlation between the El Niño 1+2 index and mean precipitation values at San Carlos station

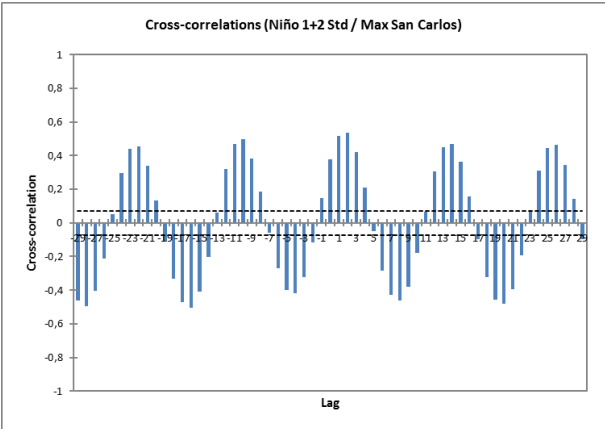


Figure 96 Cross-correlation between the El Niño 1+2 index and maximum precipitation values at San Carlos station

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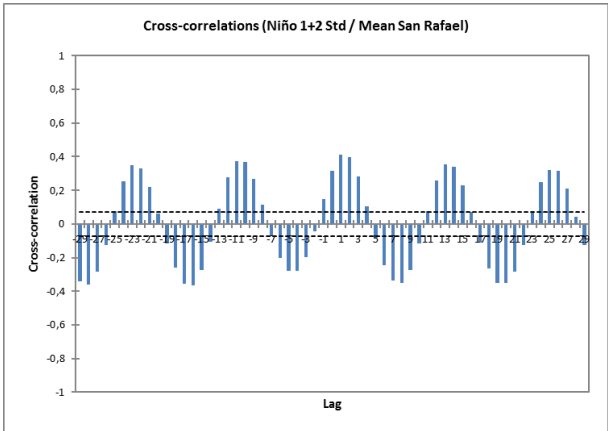


Figure 97 Cross-correlation between the El Niño 1+2 index and mean precipitation values at San Rafael station

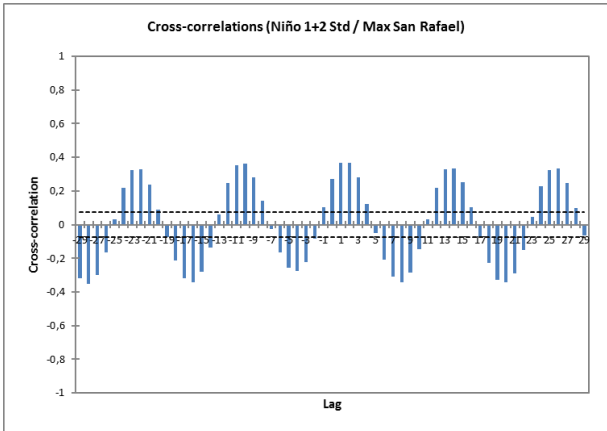


Figure 98 Cross-correlation between the El Niño 1+2 index and maximum precipitation values at San Rafael station

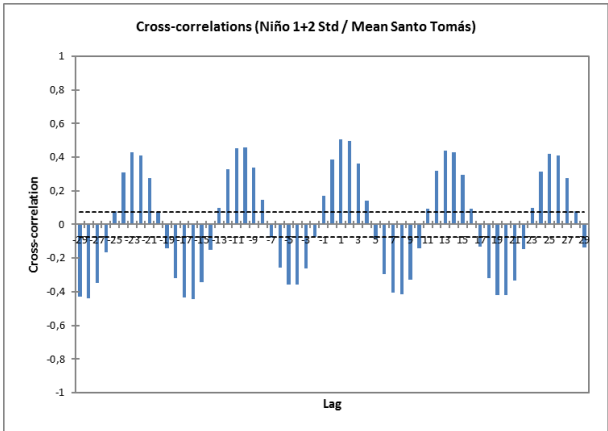


Figure 99 Cross-correlation between the El Niño 1+2 index and mean precipitation values at Santo Tomás station

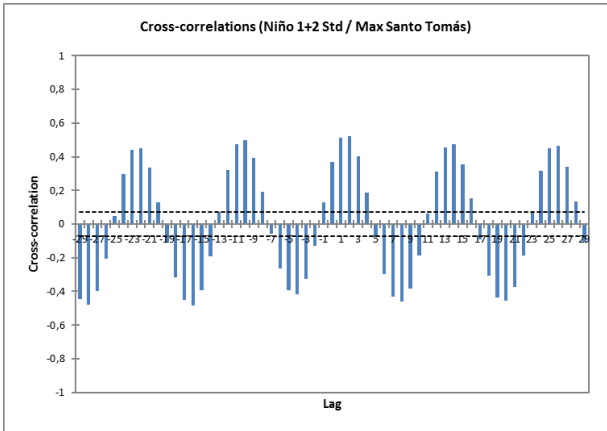


Figure 100 Cross-correlation between the El Niño 1+2 index and maximum precipitation values at Santo Tomás station

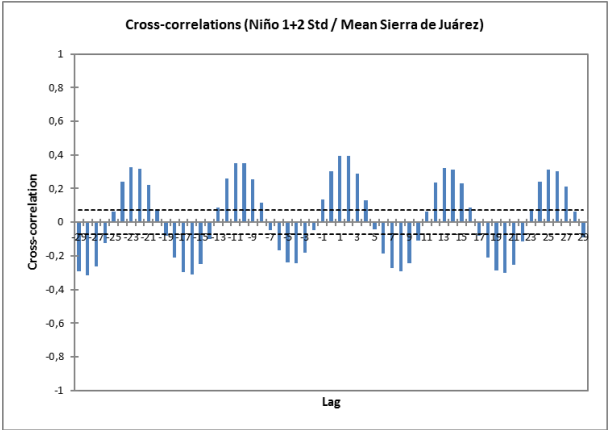


Figure 101 Cross-correlation between the El Niño 1+2 index and mean precipitation values at Sierra de Juárez station

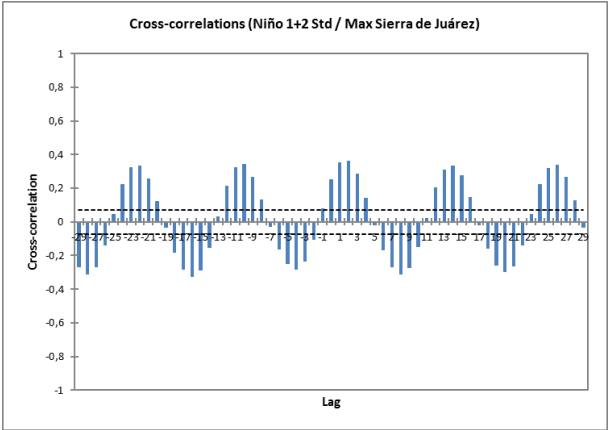


Figure 102 Cross-correlation between the El Niño 1+2 index and maximum precipitation values at Sierra de Juárez station

El Niño 3

Starting from the next page, the figures representing the cross-correlation test results between the El Niño 3 index and the mean and maximum values of the following stations: Presa ELZ, Ejido Uruapan, El Álamo, El Ciprés, El Farito, Héroes de la Independencia, La Bocana, Maneadero, Ojos Negros, Olivares Mexicanos, Punta Banda, Real del Castillo, San Rafael, Santo Tomás and Sierra de Juárez.

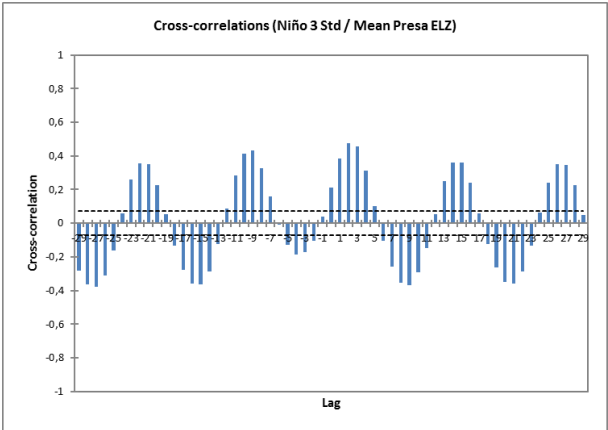


Figure 103 Cross-correlation between the El Niño 3 index and mean precipitation values at Presa ELZ station

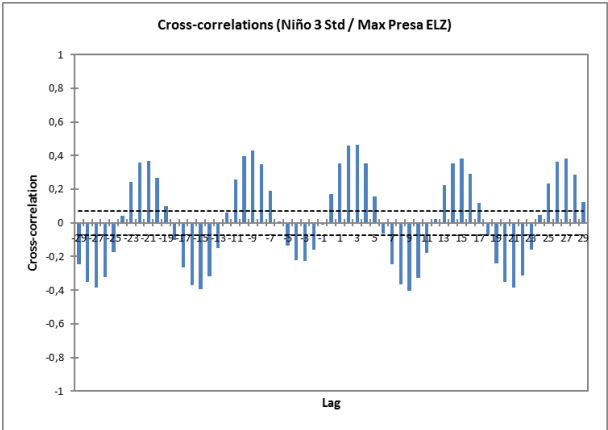


Figure 104 Cross-correlation between the El Niño 3 index and maximum precipitation values at Presa ELZ station

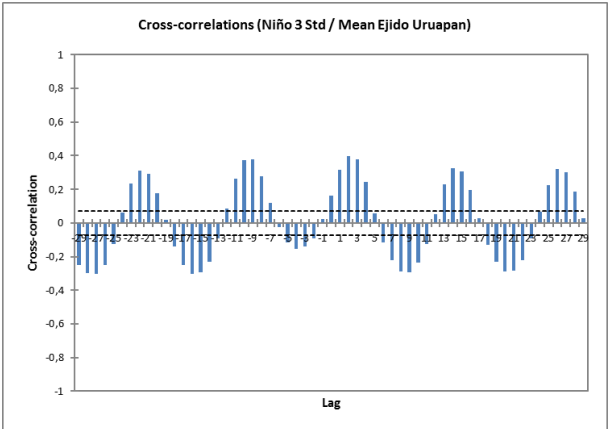


Figure 105 Cross-correlation between the El Niño 3 index and mean precipitation values at Ejido Uruapan station

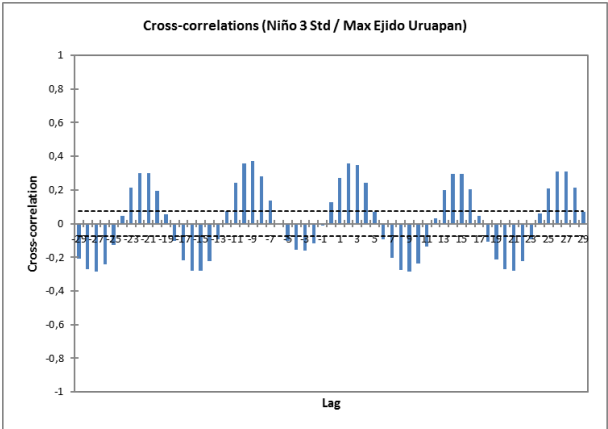


Figure 106 Cross-correlation between the El Niño 3 index and maximum precipitation values at Ejido Uruapan station

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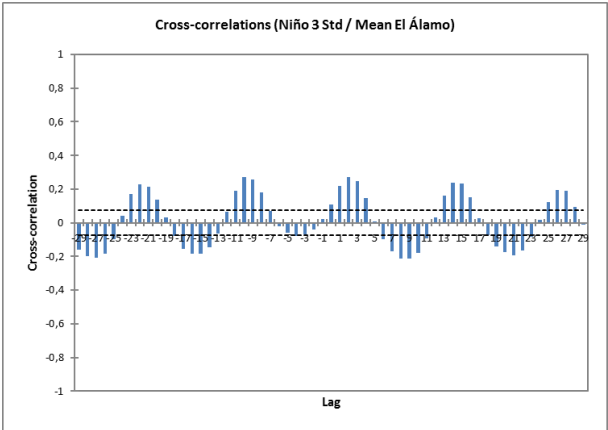


Figure 107 Cross-correlation between the El Niño 3 index and mean precipitation values at El Álamo station

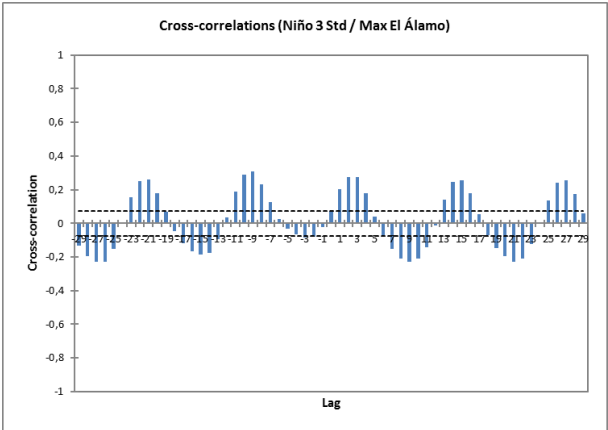


Figure 108 Cross-correlation between the El Niño 3 index and maximum precipitation values at El Álamo station

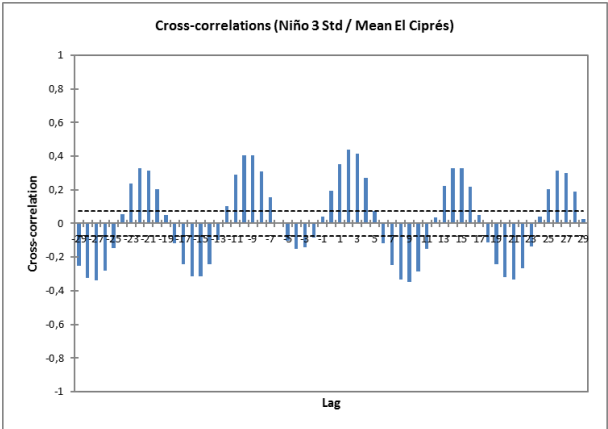


Figure 109 Cross-correlation between the El Niño 3 index and mean precipitation values at El Ciprés station

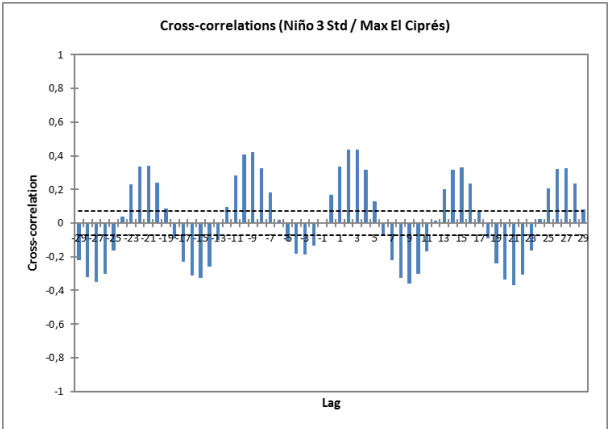


Figure 110 Cross-correlation between the El Niño 3 index and maximum precipitation values at El Ciprés station

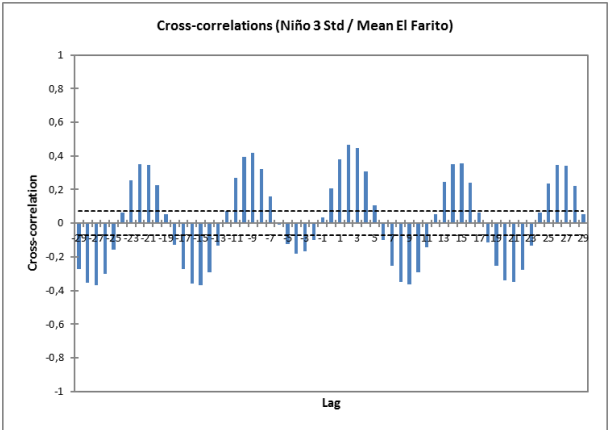


Figure 111 Cross-correlation between the El Niño 3 index and mean precipitation values at El Farito station

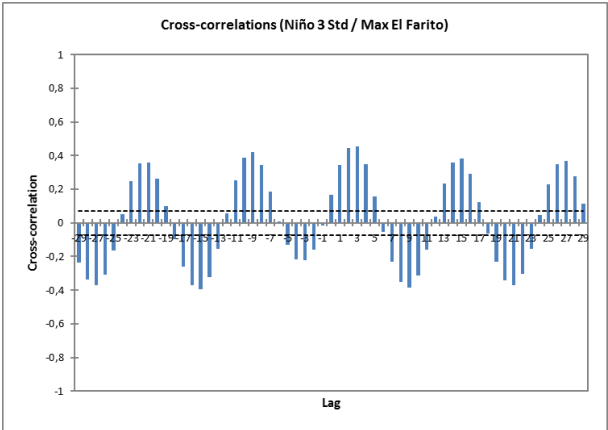


Figure 112 Cross-correlation between the El Niño 3 index and maximum precipitation values at El Farito station

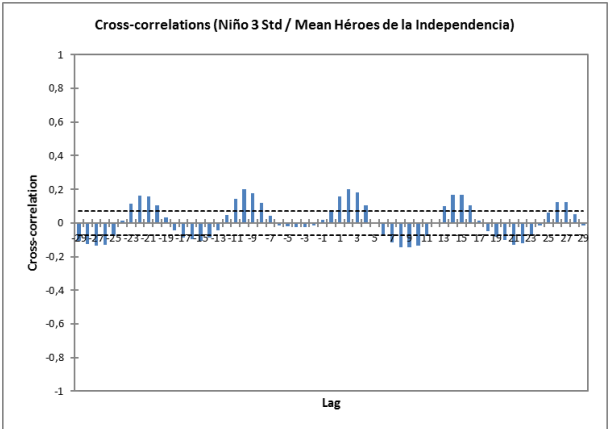


Figure 113 Cross-correlation between the El Niño 3 index and mean precipitation values at Héroes de la Independencia station

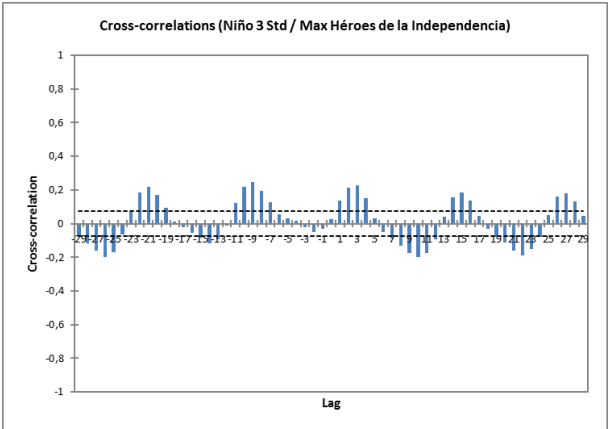


Figure 114 Cross-correlation between the El Niño 3 index and maximum precipitation values at Héroes de la Independencia station

Rainfall Characterization of the Catchment Area of Ensenada, Baja California, México

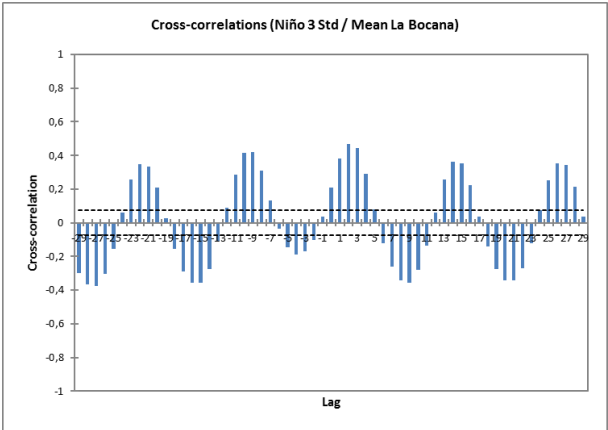


Figure 115 Cross-correlation between the El Niño 3 index and mean precipitation values at La Bocana station

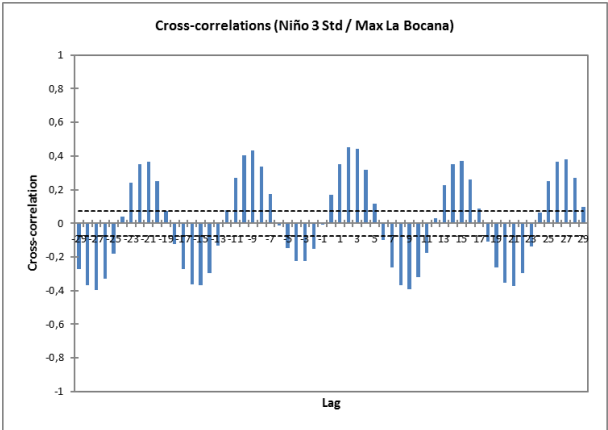


Figure 116 Cross-correlation between the El Niño 3 index and maximum precipitation values at La Bocana station

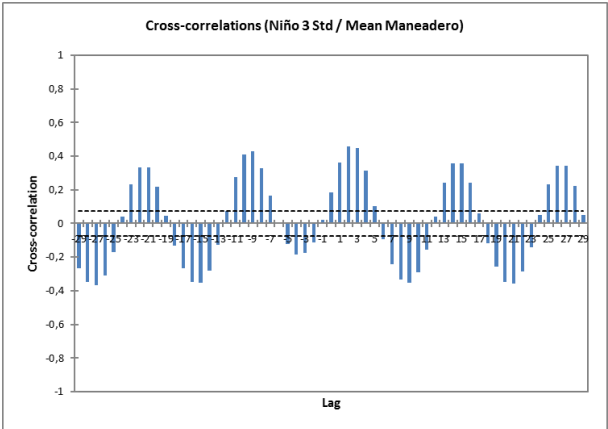


Figure 117 Cross-correlation between the El Niño 3 index and mean precipitation values at Maneadero station

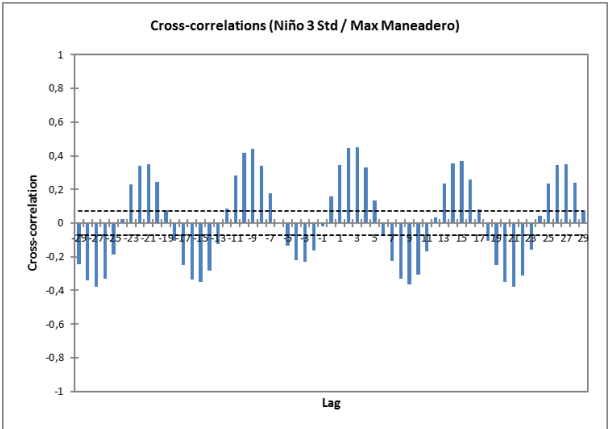


Figure 118 Cross-correlation between the El Niño 3 index and maximum precipitation values at Maneadero station

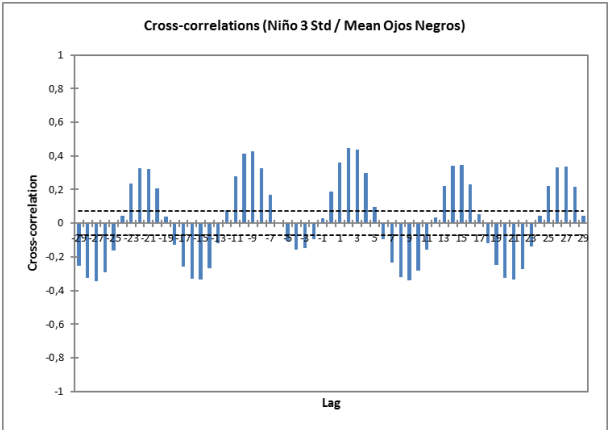


Figure 119 Cross-correlation between the El Niño 3 index and mean precipitation values at Ojos Negros station

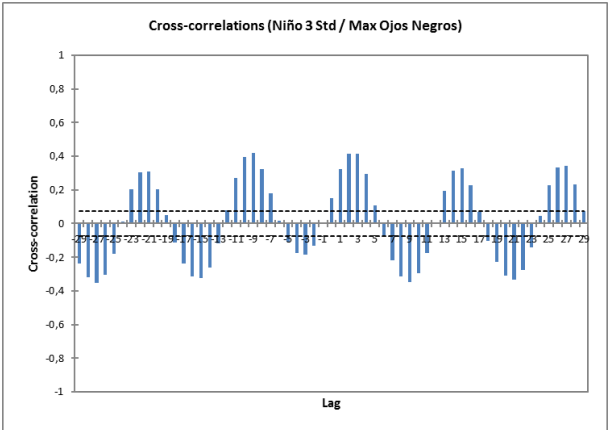


Figure 120 Cross-correlation between the El Niño 3 index and maximum precipitation values at Ojos Negros station

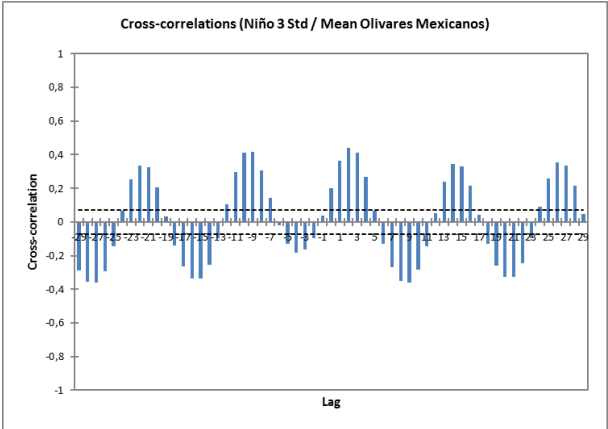


Figure 121 Cross-correlation between the El Niño 3 index and mean precipitation values at Olivares Mexicanos station

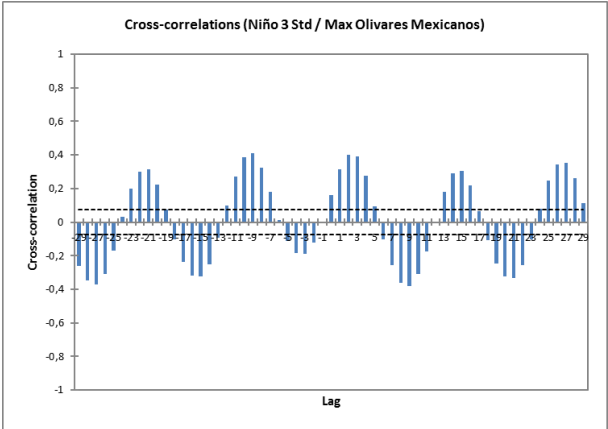


Figure 122 Cross-correlation between the El Niño 3 index and maximum precipitation values at Olivares Mexicanos station

Rainfall Characterization of the Catchment Area of Ensenada, Baja California, México

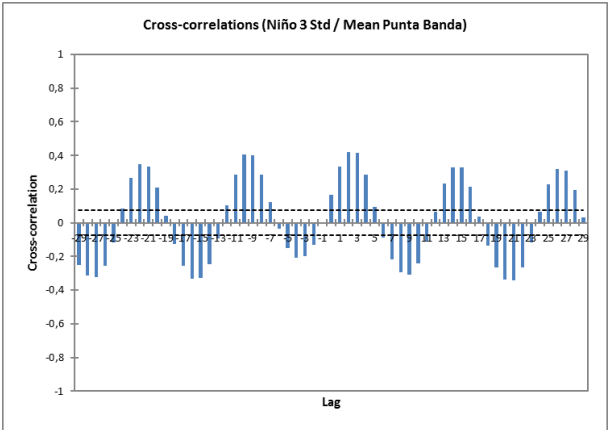


Figure 123 Cross-correlation between the El Niño 3 index and mean precipitation values at Punta Banda station

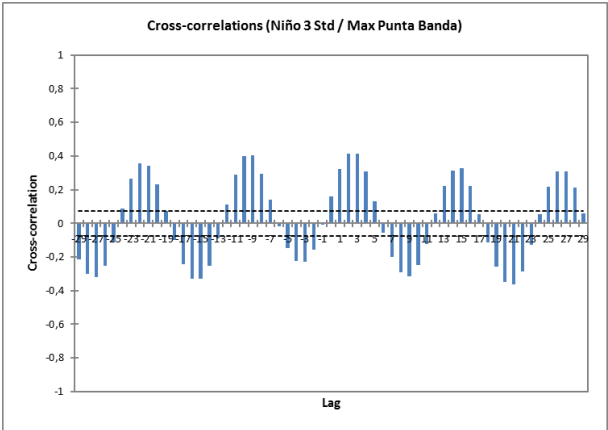


Figure 124 Cross-correlation between the El Niño 3 index and maximum precipitation values at Punta Banda station

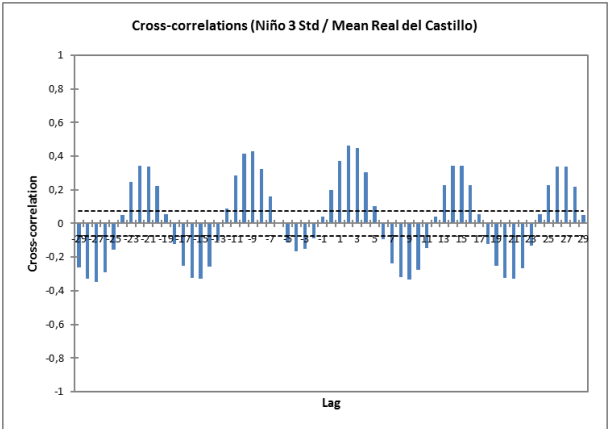


Figure 125 Cross-correlation between the El Niño 3 index and mean precipitation values at Real del Castillo station

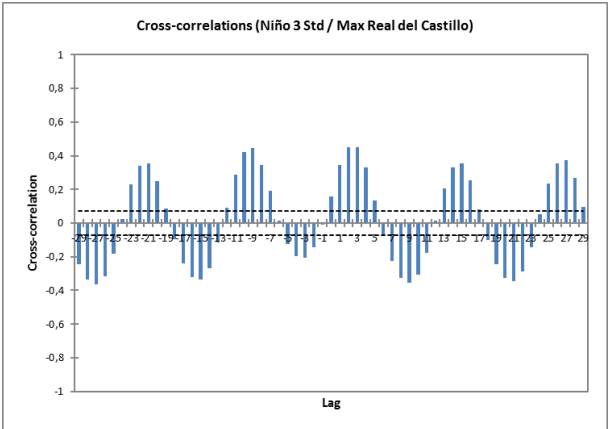


Figure 126 Cross-correlation between the El Niño 3 index and maximum precipitation values at Real del Castillo station

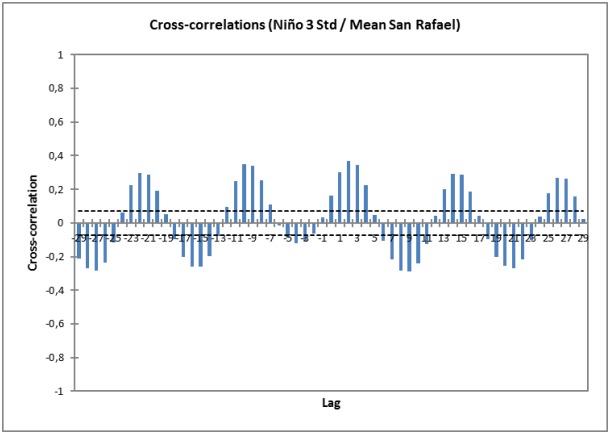


Figure 127 Cross-correlation between the El Niño 3 index and mean precipitation values at San Rafael station

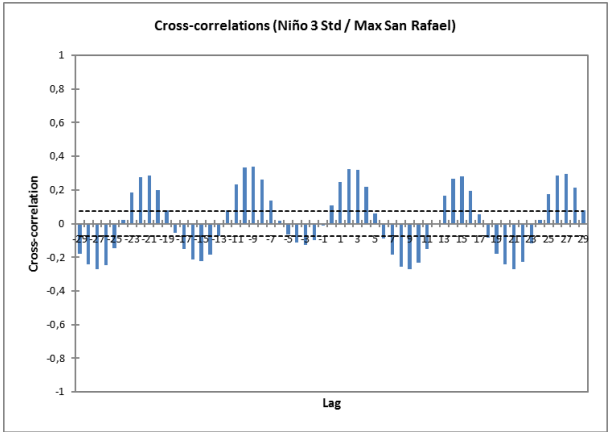


Figure 128 Cross-correlation between the El Niño 3 index and maximum precipitation values at San Rafael station

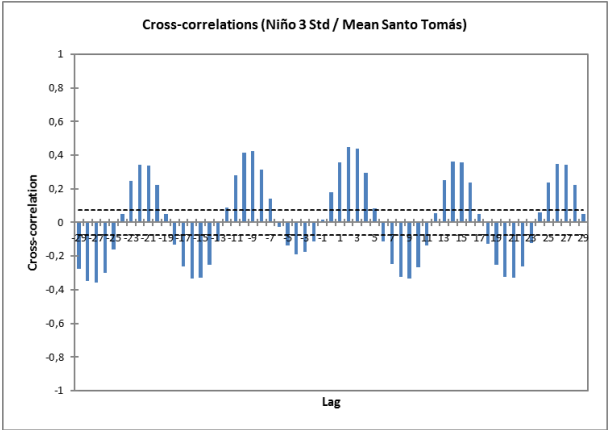


Figure 129 Cross-correlation between the El Niño 3 index and mean precipitation values at Santo Tomás station

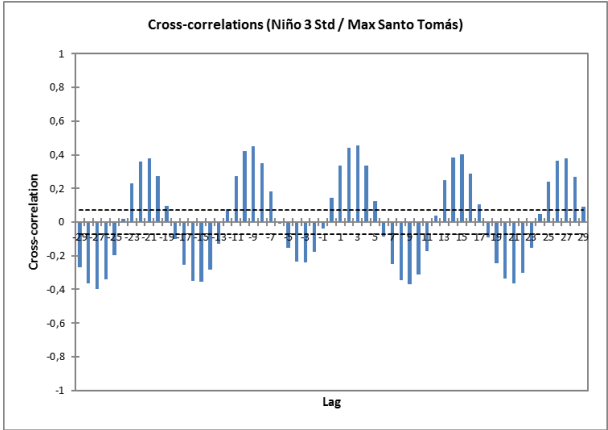


Figure 130 Cross-correlation between the El Niño 3 index and maximum precipitation values at Santo Tomás station

Rainfall Characterization of the Catchment Area of Ensenada, Baja California, México

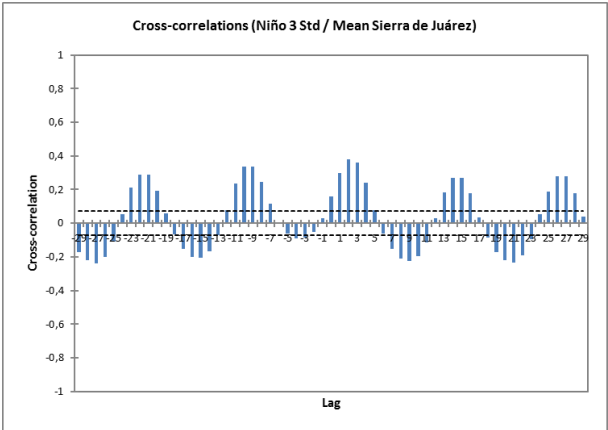


Figure 131 Cross-correlation between the El Niño 3 index and mean precipitation values at Sierra de Juárez station

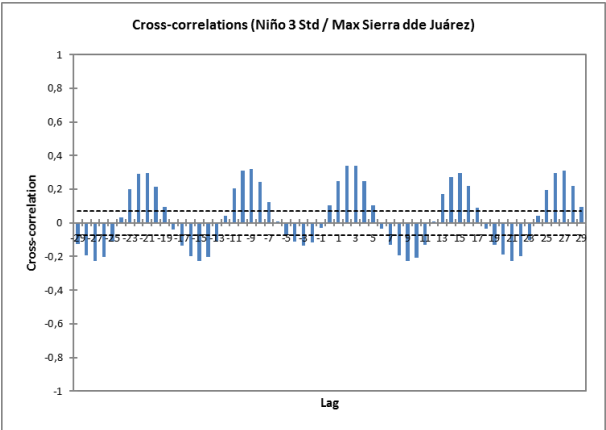


Figure 132 Cross-correlation between the El Niño 3 index and maximum precipitation values at Sierra de Juárez station

El Niño 3.4

Starting from the next page, the figures representing the cross-correlation test results between the El Niño 3.4 index and the mean and maximum values of the following stations: Presa ELZ, Ejido Uruapan, El Álamo, El Ciprés, El Farito, Héroes de la Independencia, La Bocana, Maneadero, Ojos Negros, Olivares Mexicanos, Punta Banda, San Carlos, San Rafael, Santo Tomás and Sierra de Juárez.

Rainfall Characterization of the Catchment Area of Ensenada, Baja California, México

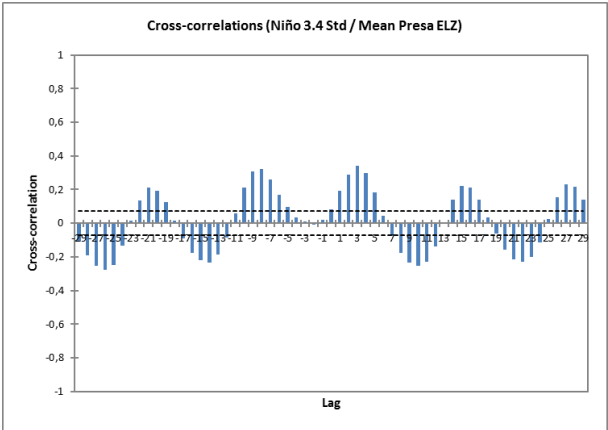


Figure 133 Cross-correlation between the El Niño 3.4 index and mean precipitation values at Presa ELZ station

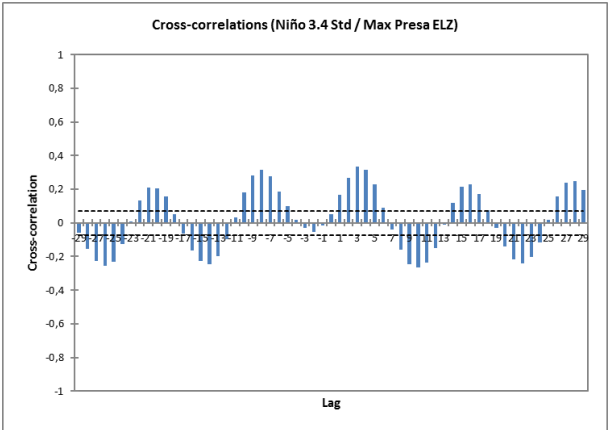


Figure 134 Cross-correlation between the El Niño 3.4 index and maximum precipitation values at Presa ELZ station

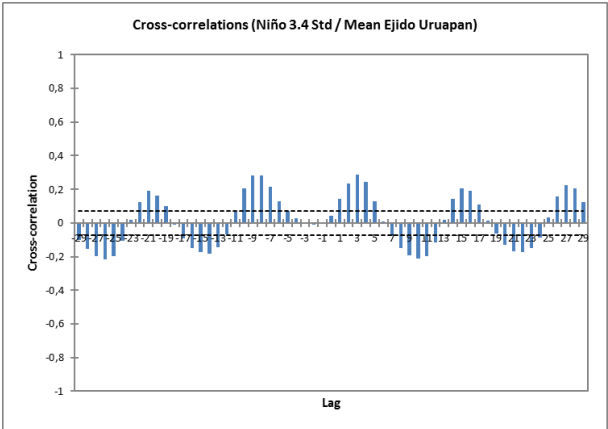


Figure 135 Cross-correlation between the El Niño 3.4 index and mean precipitation values at Ejido Uruapan station

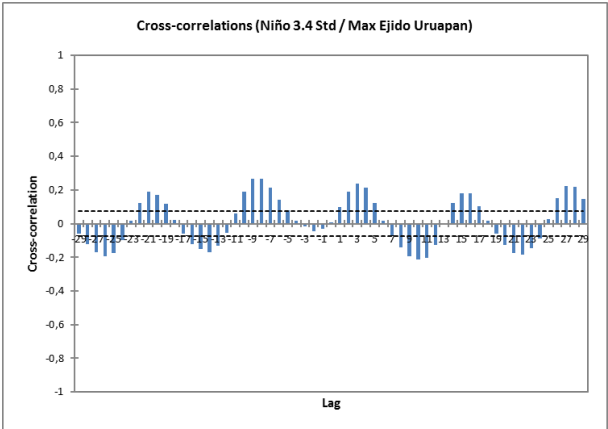


Figure 136 Cross-correlation between the El Niño 3.4 index and maximum precipitation values at Ejido Uruapan station

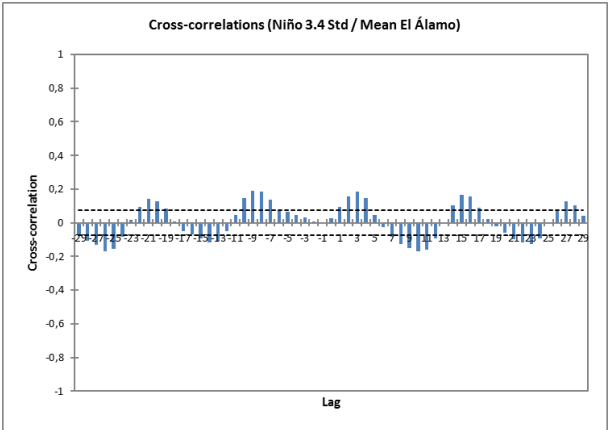


Figure 137 Cross-correlation between the El Niño 3.4 index and mean precipitation values at El Álamo station

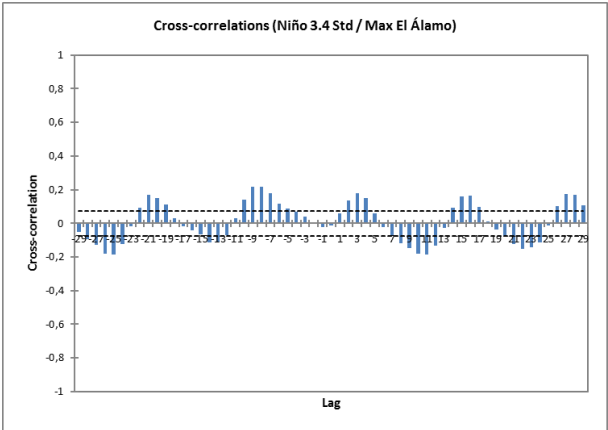


Figure 138 Cross-correlation between the El Niño 3.4 index and maximum precipitation values at El Álamo station

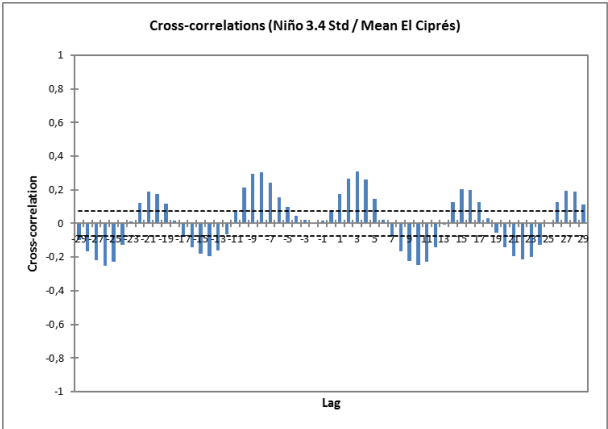


Figure 139 Cross-correlation between the El Niño 3.4 index and mean precipitation values at El Ciprés station

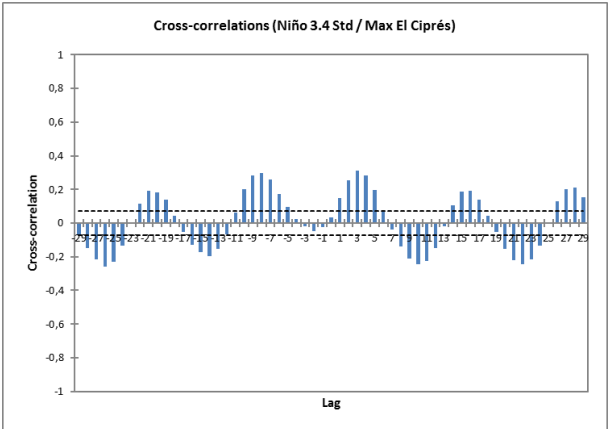


Figure 140 Cross-correlation between the El Niño 3.4 index and maximum precipitation values at El Ciprés station

Rainfall Characterization of the Catchment Area of Ensenada, Baja California, México

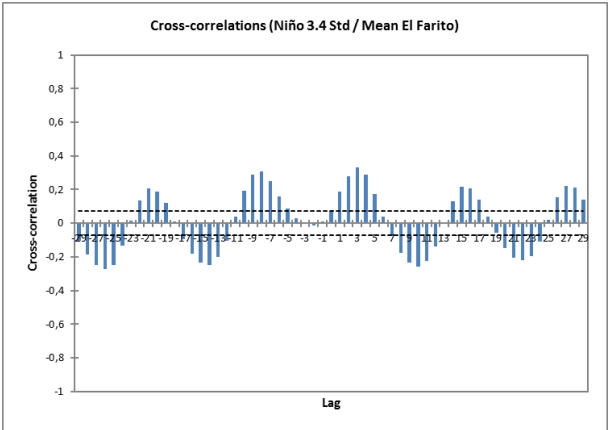


Figure 141 Cross-correlation between the El Niño 3.4 index and mean precipitation values at El Farito station

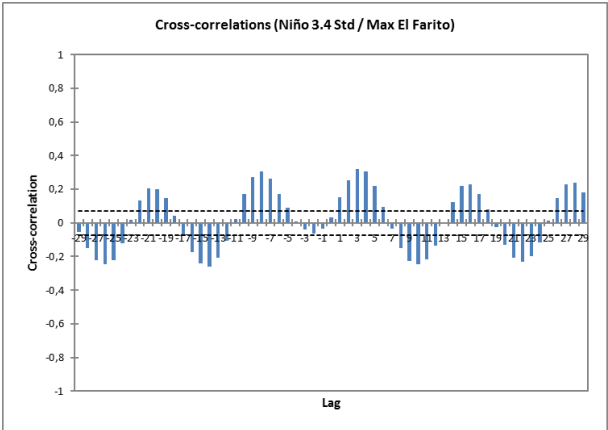


Figure 142 Cross-correlation between the El Niño 3.4 index and maximum precipitation values at El Farito station

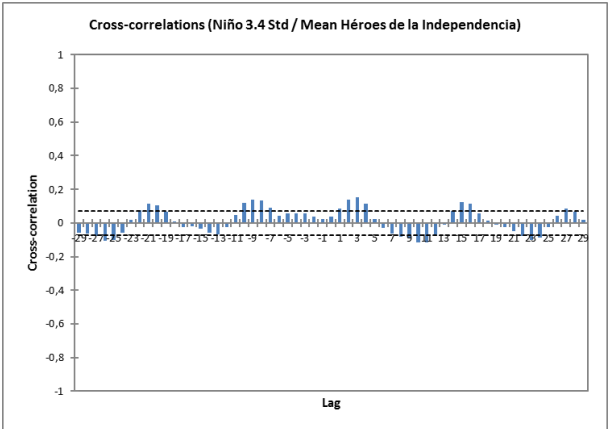


Figure 143 Cross-correlation between the El Niño 3.4 index and mean precipitation values at Héroes de la Independencia station

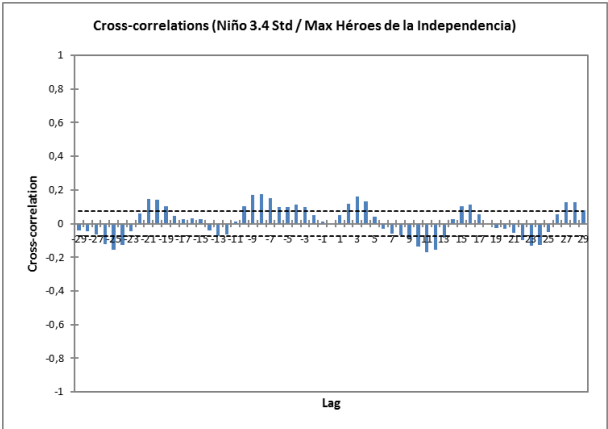


Figure 144 Cross-correlation between the El Niño 3.4 index and maximum precipitation values at Héroes de la Independencia station

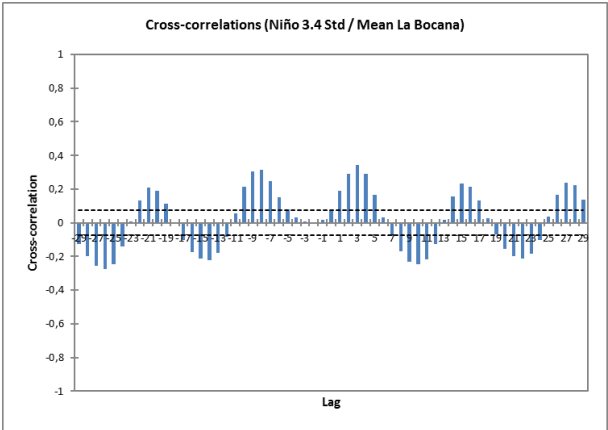


Figure 145 Cross-correlation between the El Niño 3.4 index and mean precipitation values at La Bocana station

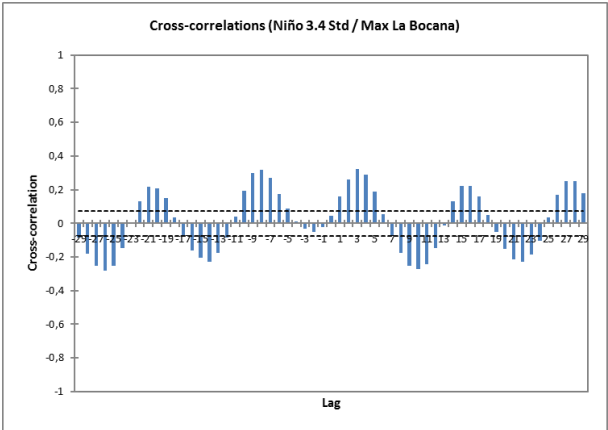


Figure 146 Cross-correlation between the El Niño 3.4 index and maximum precipitation values at La Bocana station

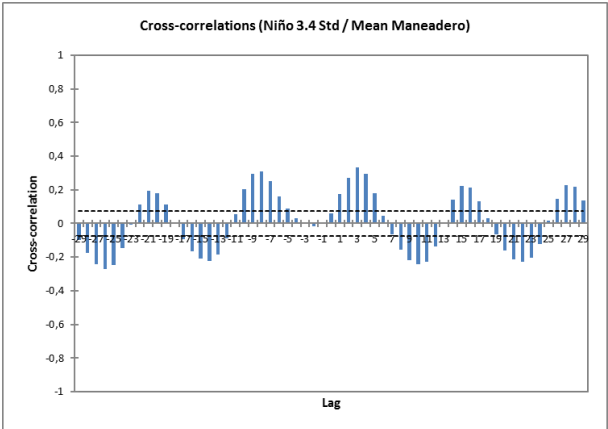


Figure 147 Cross-correlation between the El Niño 3.4 index and mean precipitation values at Maneadero station

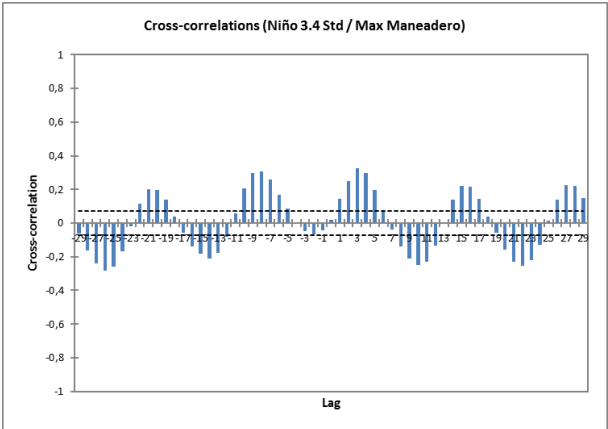


Figure 148 Cross-correlation between the El Niño 3.4 index and maximum precipitation values at Maneadero station

Rainfall Characterization of the Catchment Area of Ensenada, Baja California, México

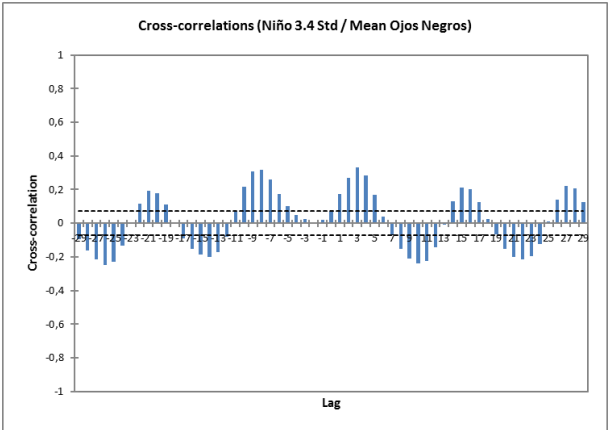


Figure 149 Cross-correlation between the El Niño 3.4 index and mean precipitation values at Ojos Negros station

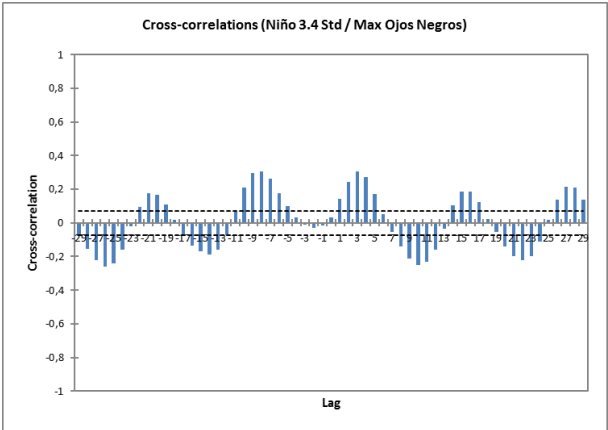


Figure 150 Cross-correlation between the El Niño 3.4 index and maximum precipitation values at Ojos Negros station

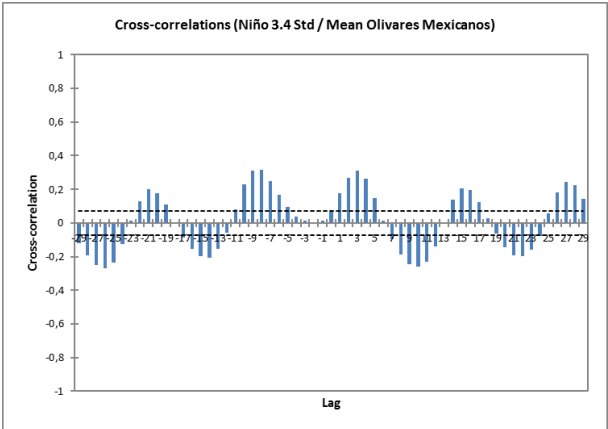


Figure 151 Cross-correlation between the El Niño 3.4 index and mean precipitation values at Olivares Mexicanos station

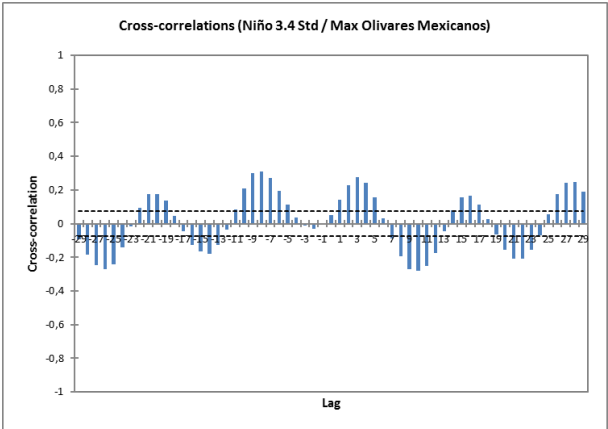


Figure 152 Cross-correlation between the El Niño 3.4 index and maximum precipitation values at Olivares Mexicanos station

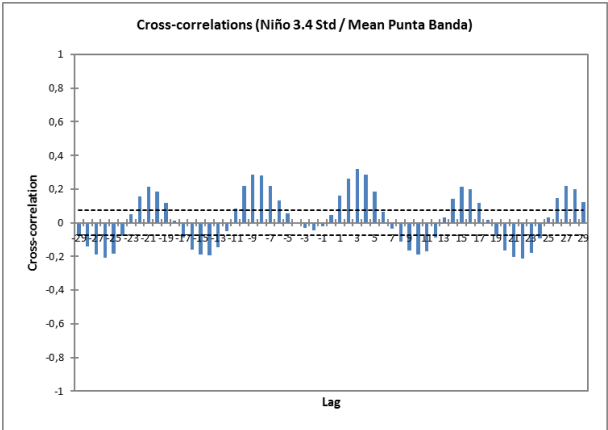


Figure 153 Cross-correlation between the El Niño 3.4 index and mean precipitation values at Punta Banda station

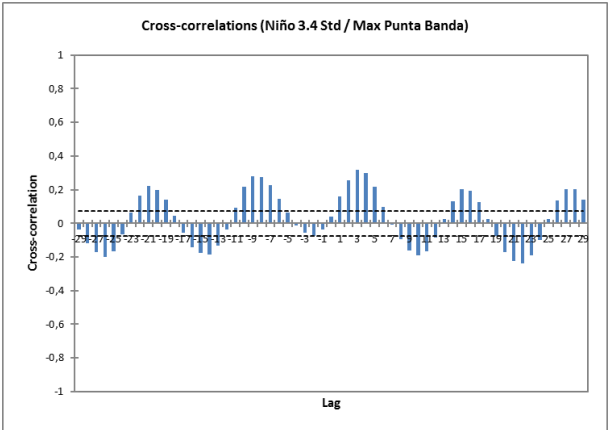


Figure 154 Cross-correlation between the El Niño 3.4 index and maximum precipitation values at Punta Banda station

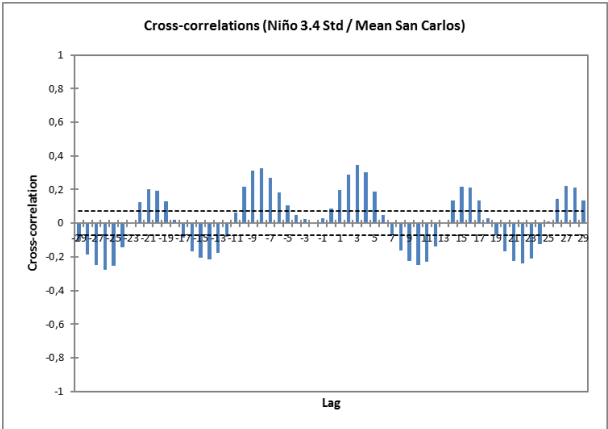


Figure 155 Cross-correlation between the El Niño 3.4 index and mean precipitation values at San Carlos station

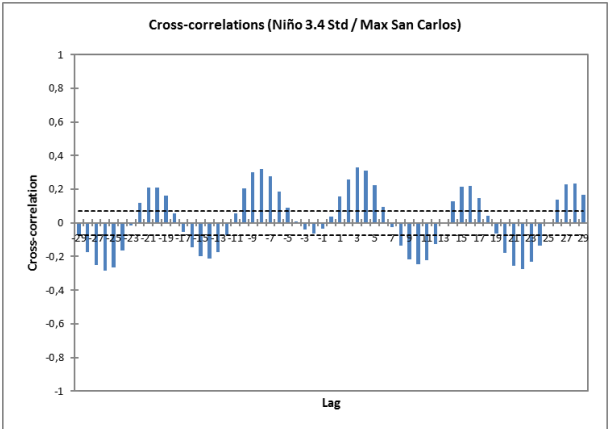


Figure 156 Cross-correlation between the El Niño 3.4 index and maximum precipitation values at San Carlos station

Rainfall Characterization of the Catchment Area of Ensenada, Baja California, México

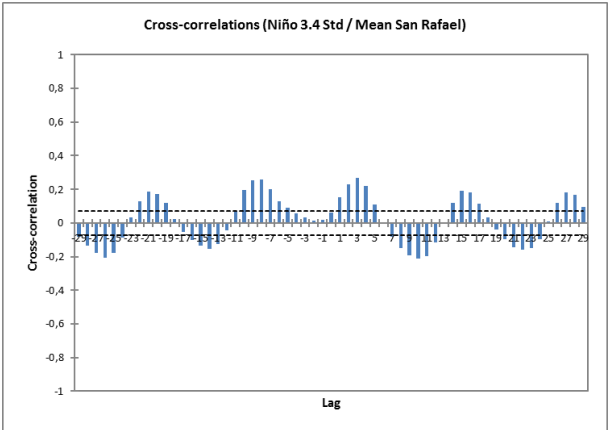


Figure 157 Cross-correlation between the El Niño 3.4 index and mean precipitation values at San Rafael station

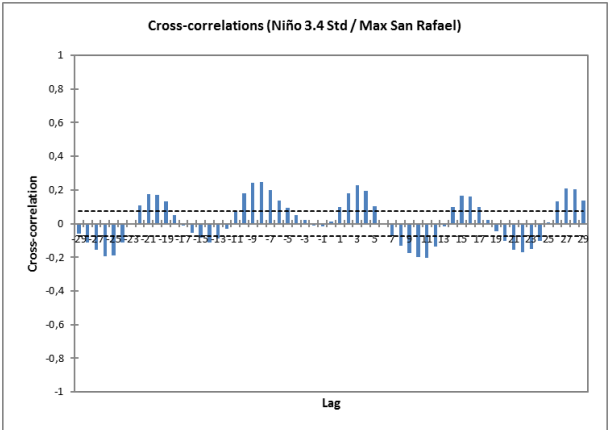


Figure 158 Cross-correlation between the El Niño 3.4 index and maximum precipitation values at San Rafael station

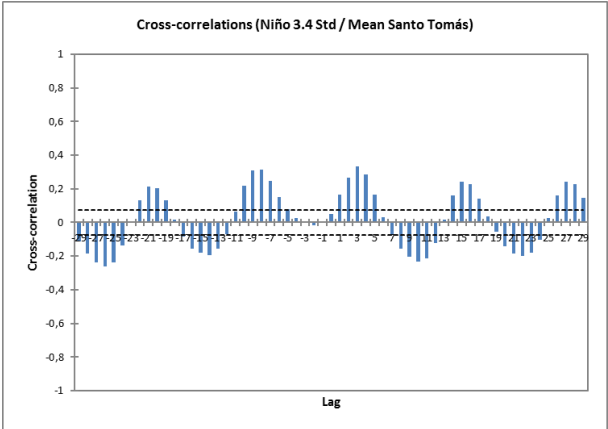


Figure 159 Cross-correlation between the El Niño 3.4 index and mean precipitation values at Santo Tomás station

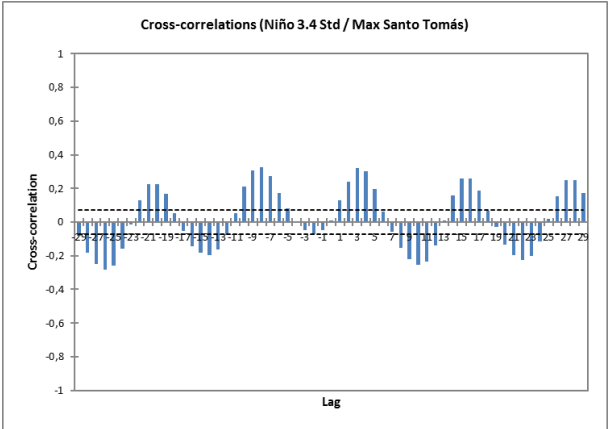


Figure 160 Cross-correlation between the El Niño 3.4 index and maximum precipitation values at Santo Tomás station

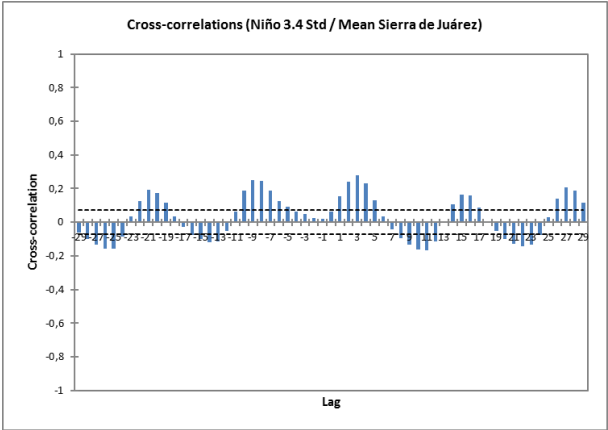


Figure 161 Cross-correlation between the El Niño 3.4 index and mean precipitation values at Sierra de Juárez station

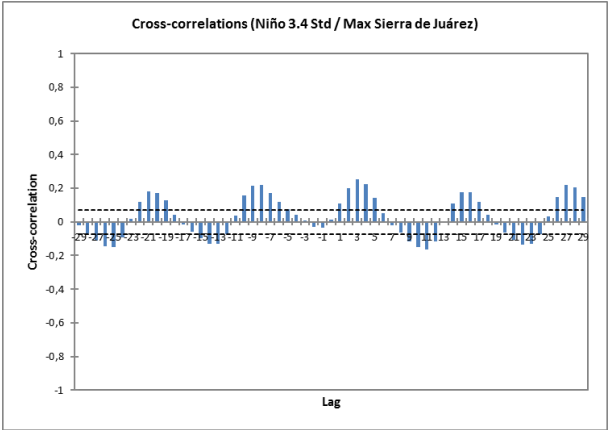


Figure 162 Cross-correlation between the El Niño 3.4 index and maximum precipitation values at Sierra de Juárez station

El Niño 4

Starting from the next page, the figures representing the cross-correlation test results between the El Niño 1+2 index and the mean and maximum values of the following stations: Presa ELZ, Ejido Uruapan, El Álamo, El Ciprés, El Farito, Héroes de la Independencia, La Bocana, Maneadero, Ojos Negros, Punta Banda, Real del Castillo, San Carlos, San Rafael, Santo Tomás and Sierra de Juárez.

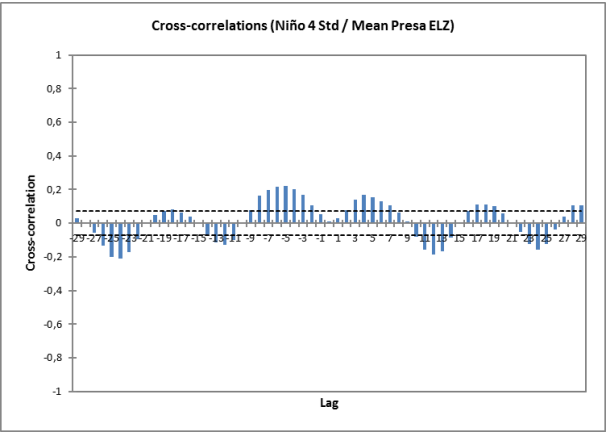


Figure 163 Cross-correlation between the El Niño 4 index and mean precipitation values at Presa ELZ station

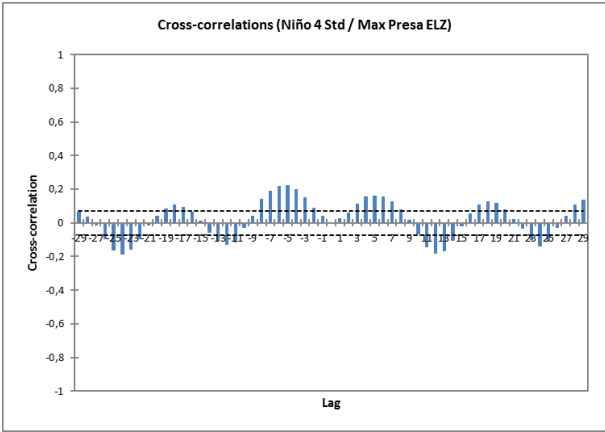


Figure 164 Cross-correlation between the El Niño 4 index and maximum precipitation values at Presa ELZ station

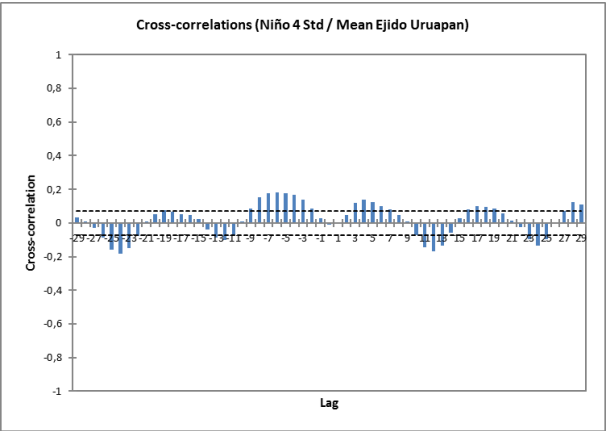


Figure 165 Cross-correlation between the El Niño 4 index and mean precipitation values at Ejido Uruapan station

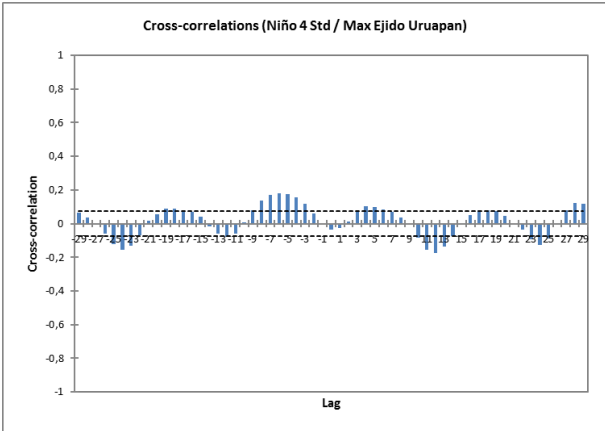


Figure 166 Cross-correlation between the El Niño 4 index and maximum precipitation values at Ejido Uruapan station

Rainfall Characterization of the Catchment Area of Ensenada, Baja California, México

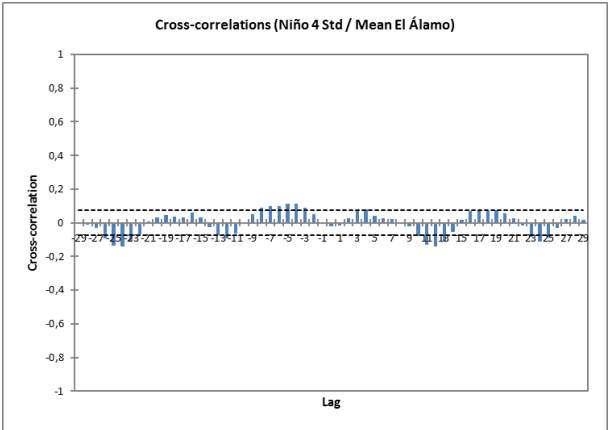


Figure 167 Cross-correlation between the El Niño 4 index and mean precipitation values at El Álamo station

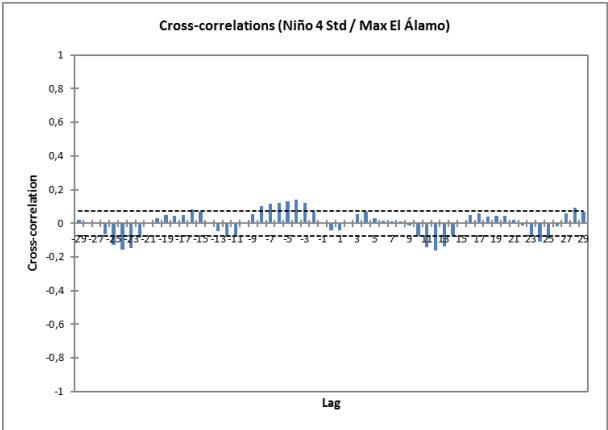


Figure 168 Cross-correlation between the El Niño 4 index and maximum precipitation values at El Álamo station

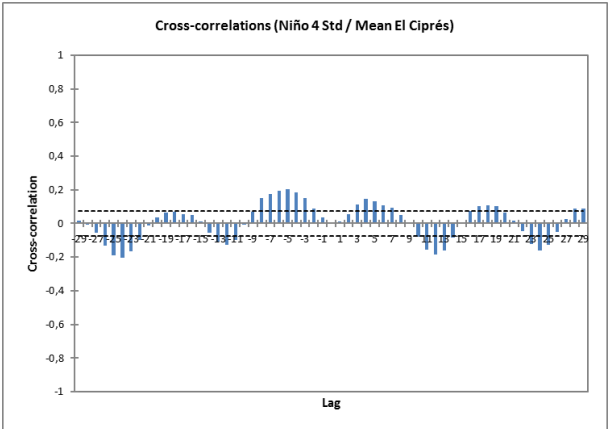


Figure 169 Cross-correlation between the El Niño 4 index and mean precipitation values at El Ciprés station

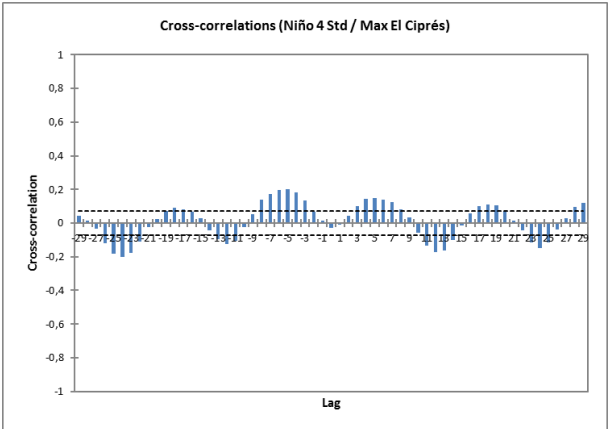


Figure 170 Cross-correlation between the El Niño 4 index and maximum precipitation values at El Ciprés station

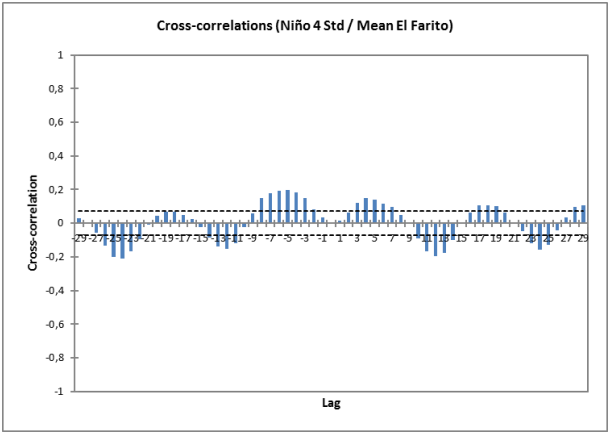


Figure 171 Cross-correlation between the El Niño 4 index and mean precipitation values at El Farito station

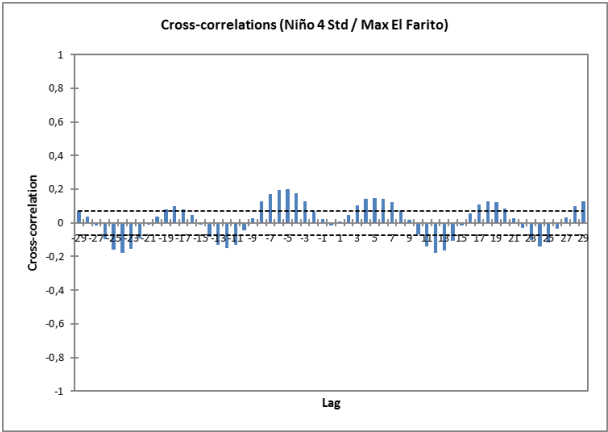


Figure 172 Cross-correlation between the El Niño 4 index and maximum precipitation values at El Farito station



Figure 173 Cross-correlation between the El Niño 4 index and mean precipitation values at Héroes de la Independencia station

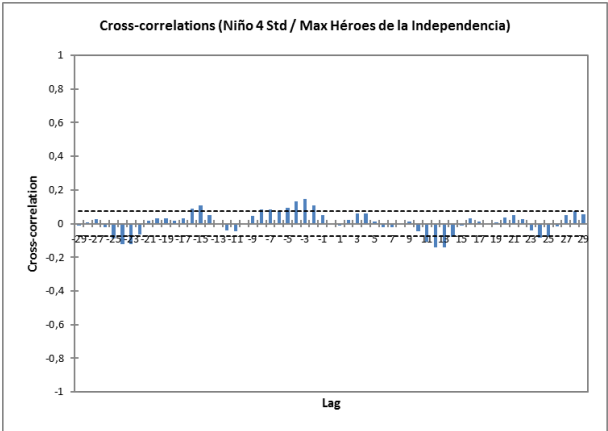


Figure 174 Cross-correlation between the El Niño 4 index and maximum precipitation values at Héroes de la Independencia station

Rainfall Characterization of the Catchment Area of Ensenada, Baja California, México

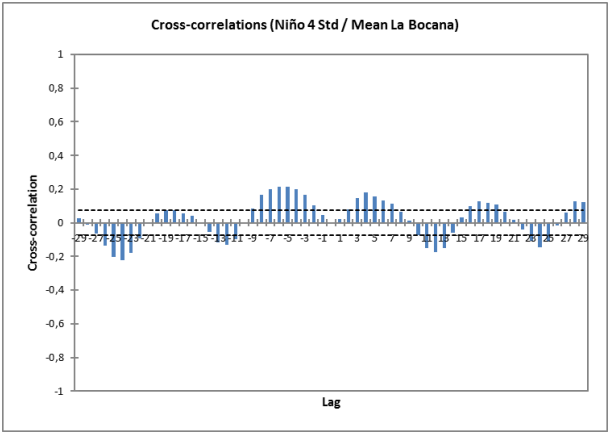


Figure 175 Cross-correlation between the El Niño 4 index and mean precipitation values at La Bocana station

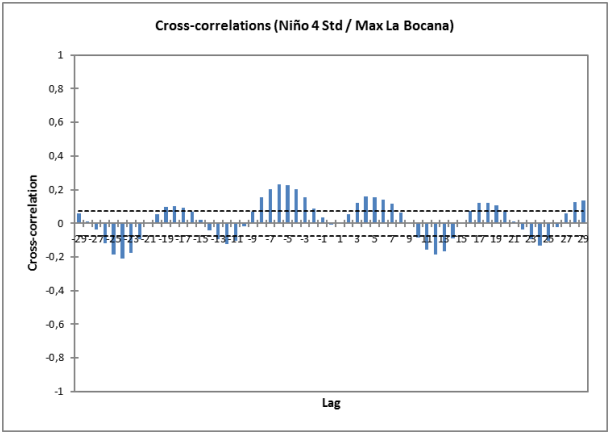


Figure 176 Cross-correlation between the El Niño 4 index and maximum precipitation values at La Bocana station

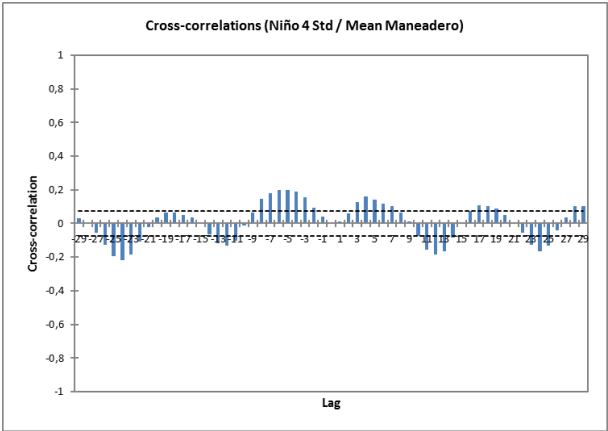


Figure 177 Cross-correlation between the El Niño 4 index and mean precipitation values at Maneadero station

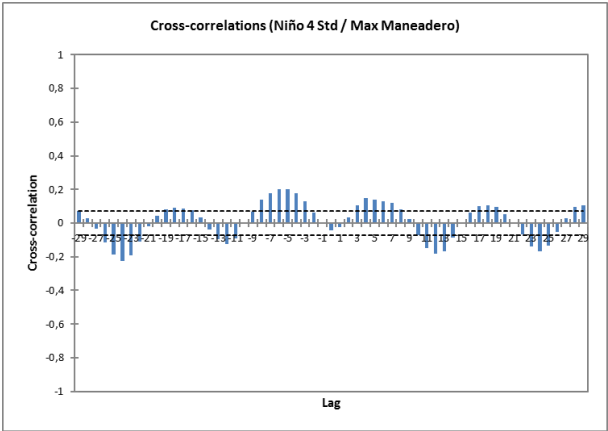


Figure 178 Cross-correlation between the El Niño 4 index and maximum precipitation values at Maneadero station

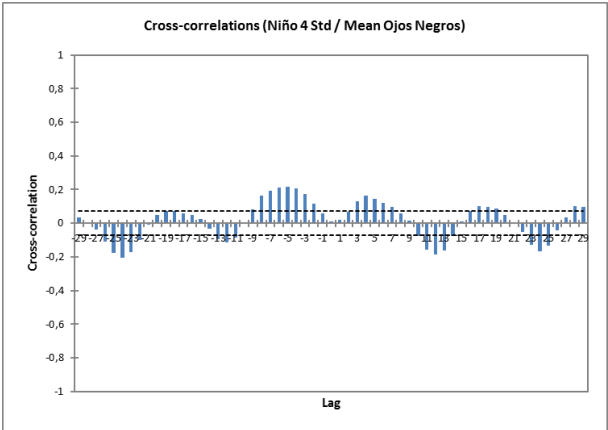


Figure 179 Cross-correlation between the El Niño 4 index and mean precipitation values at Ojos Negros station

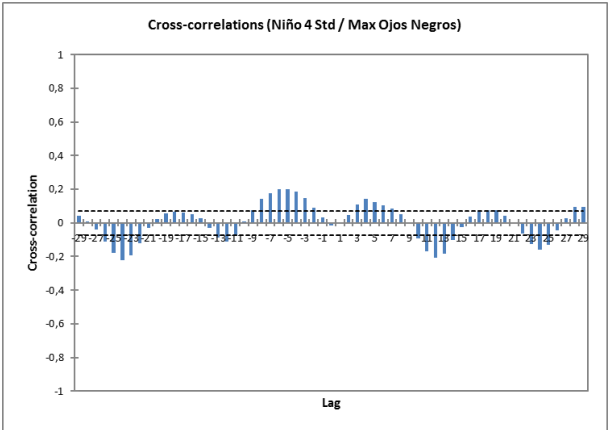


Figure 180 Cross-correlation between the El Niño 4 index and maximum precipitation values at Ojos Negros station

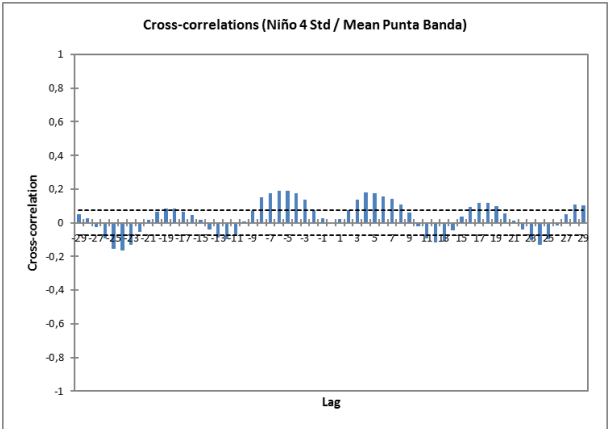


Figure 181 Cross-correlation between the El Niño 4 index and mean precipitation values at Punta Banda station

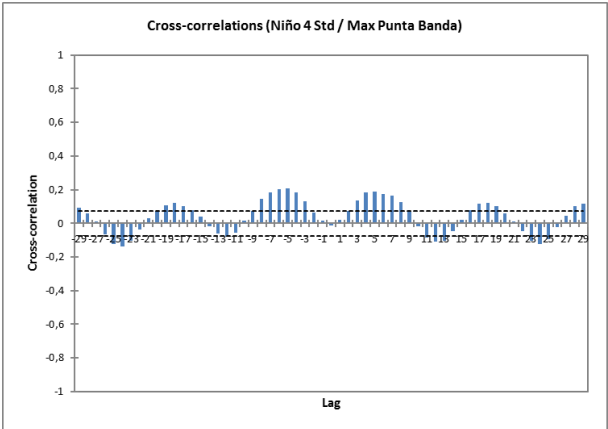


Figure 182 Cross-correlation between the El Niño 4 index and maximum precipitation values at Punta Banda station

Rainfall Characterization of the Catchment Area of Ensenada, Baja California, México

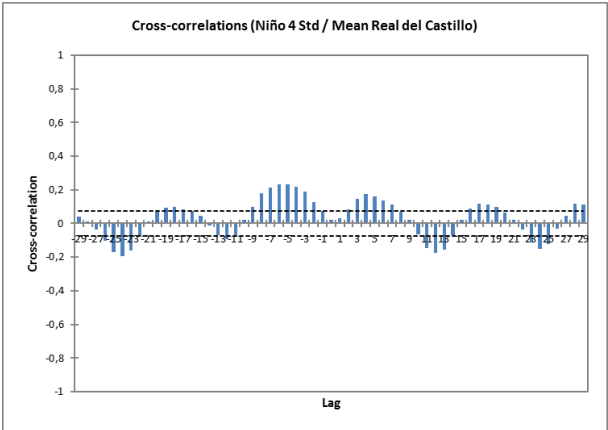


Figure 183 Cross-correlation between the El Niño 4 index and mean precipitation values at Real del Castillo station

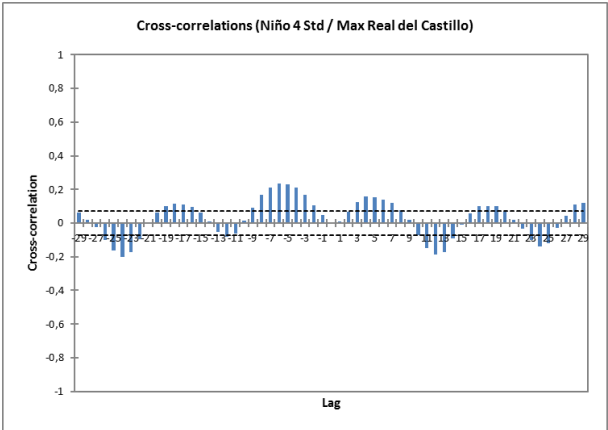


Figure 184 Cross-correlation between the El Niño 4 index and maximum precipitation values at Real del Castillo station

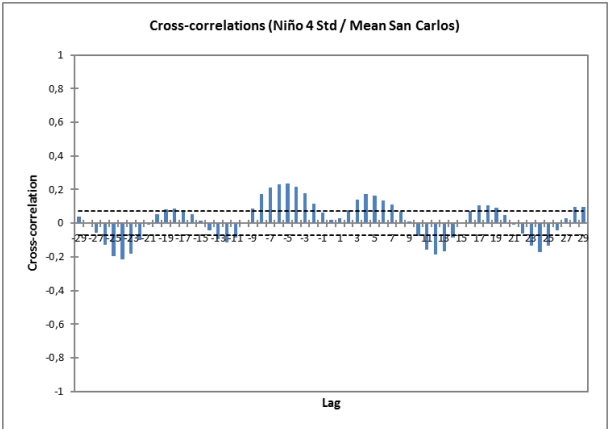


Figure 185 Cross-correlation between the El Niño 4 index and mean precipitation values at San Carlos station

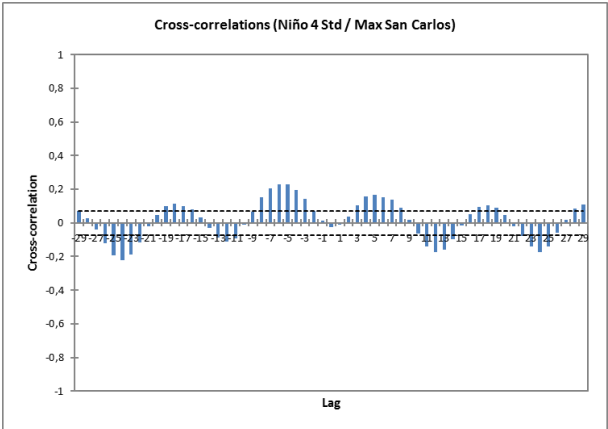


Figure 186 Cross-correlation between the El Niño 4 index and maximum precipitation values at San Carlos station

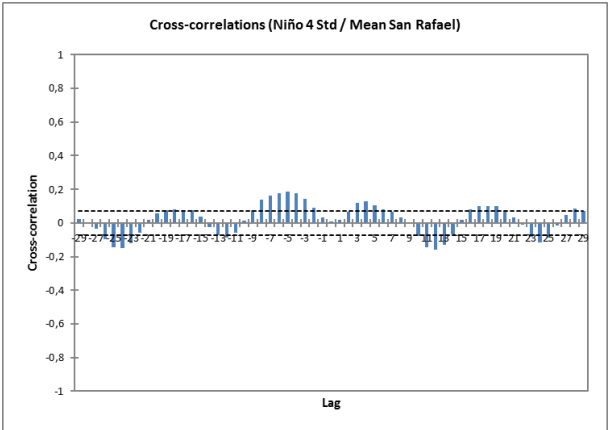


Figure 187 Cross-correlation between the El Niño 4 index and mean precipitation values at San Rafael station

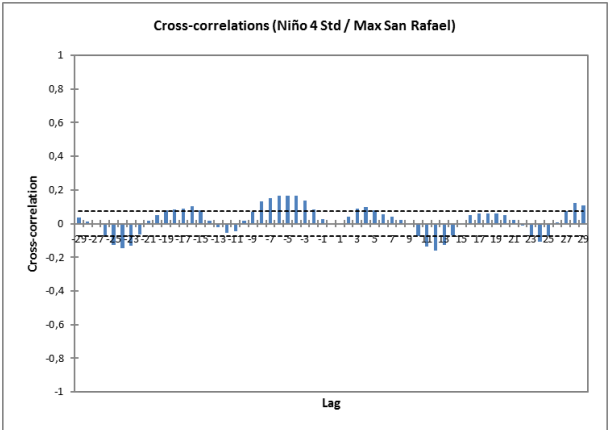


Figure 188 Cross-correlation between the El Niño 4 index and maximum precipitation values at San Rafael station

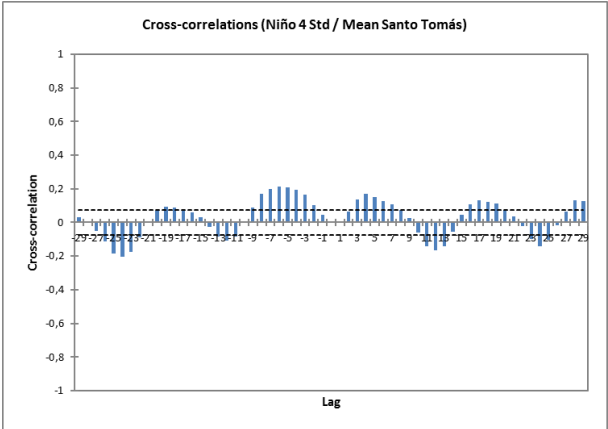


Figure 189 Cross-correlation between the El Niño 4 index and mean precipitation values at Santo Tomás station

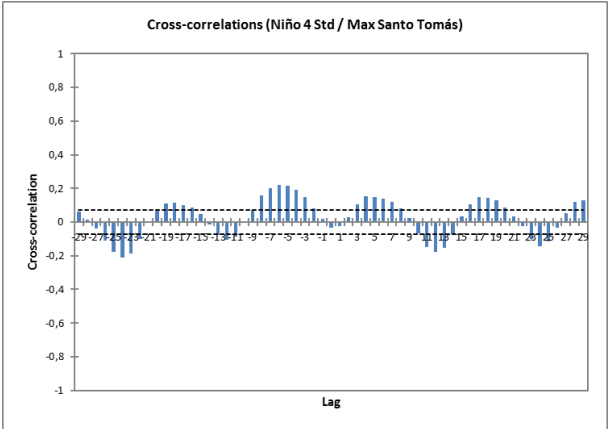


Figure 190 Cross-correlation between the El Niño 4 index and maximum precipitation values at Santo Tomás station

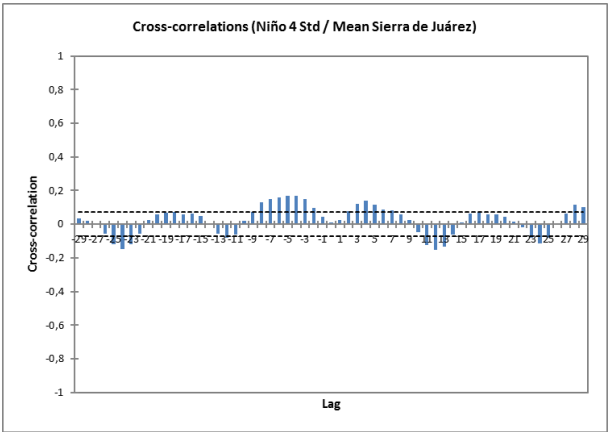


Figure 191 Cross-correlation between the El Niño 4 index and mean precipitation values at Sierra de Juárez station

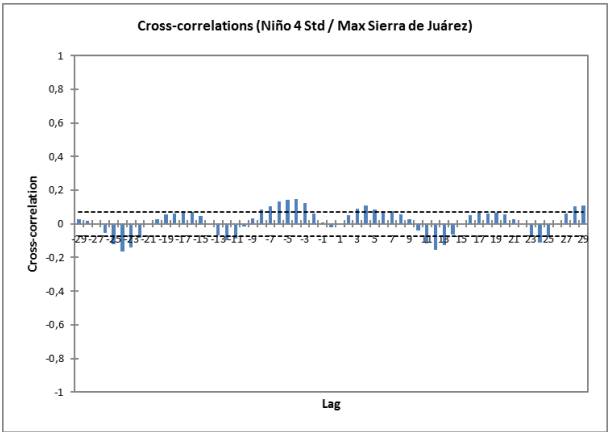


Figure 192 Cross-correlation between the El Niño 4 index and maximum precipitation values at Sierra de Juárez station

Starting from the next page, the figures representing the cross-correlation test results between the El Niño 1+2 index and the mean and maximum values of the following stations: Presa ELZ, Ejido Uruapan, El Álamo, El Ciprés, El Farito, Héroes de la Independencia, La Bocana, Ojos Negros, Olivares Mexicanos, Punta Banda, Real del Castillo, San Carlos, San Rafael, Santo Tomás and Sierra de Juárez.

Rainfall Characterization of the Catchment Area of Ensenada, Baja California, México

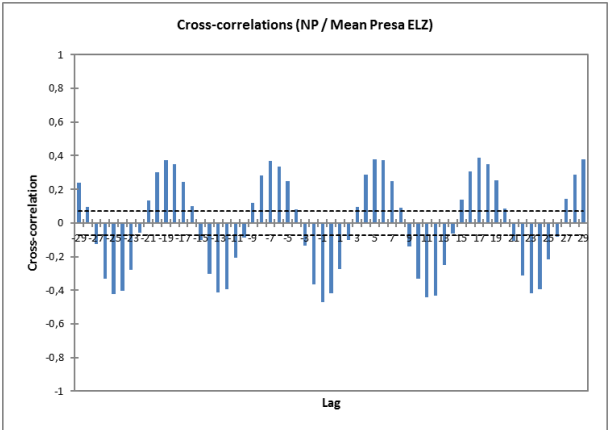


Figure 193 Cross-correlation between the NP index and mean precipitation values at Presa ELZ station

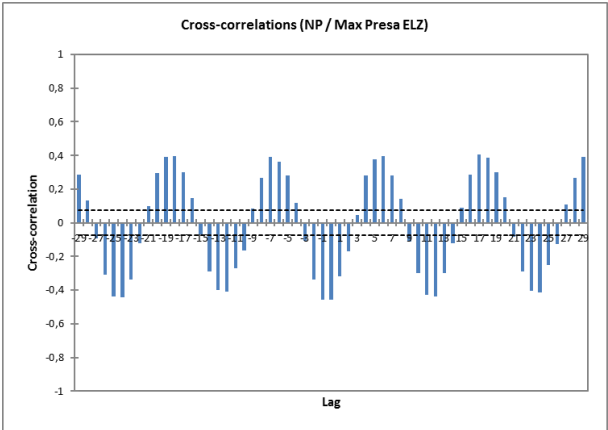


Figure 194 Cross-correlation between the NP index and maximum precipitation values at Presa ELZ station

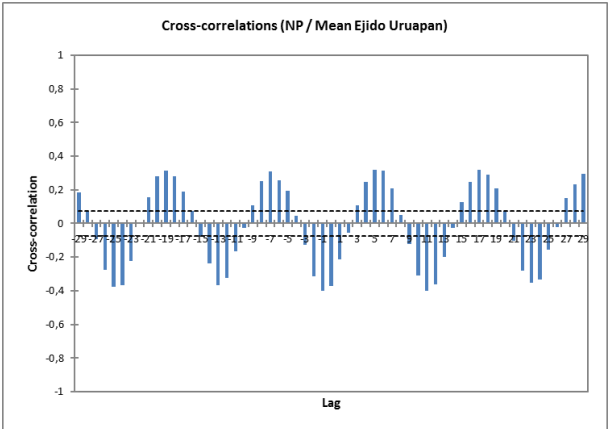


Figure 195 Cross-correlation between the NP index and mean precipitation values at Ejido Uruapan station

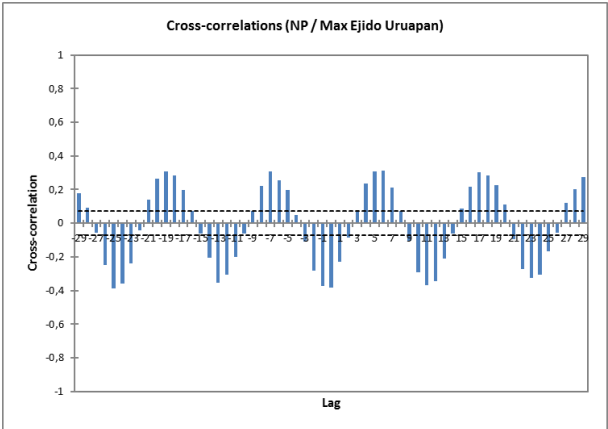


Figure 196 Cross-correlation between the NP index and maximum precipitation values at Ejido Uruapan station

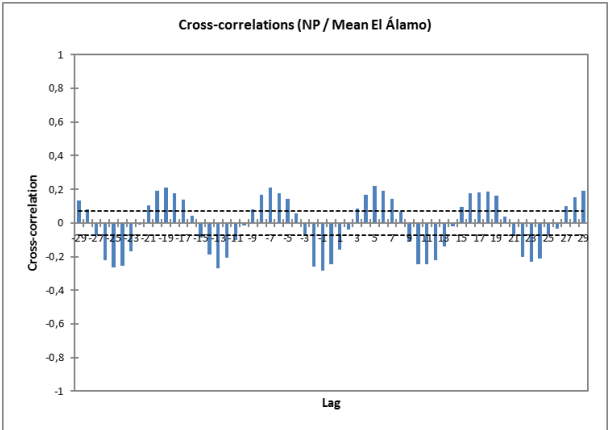


Figure 197 Cross-correlation between the NP index and mean precipitation values at El Álamo station

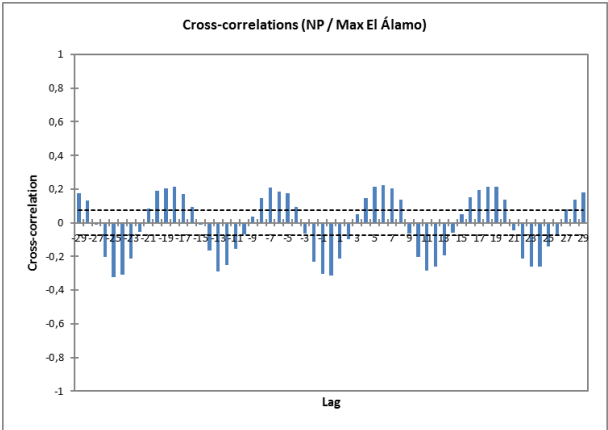


Figure 198 Cross-correlation between the NP index and maximum precipitation values at El Álamo station

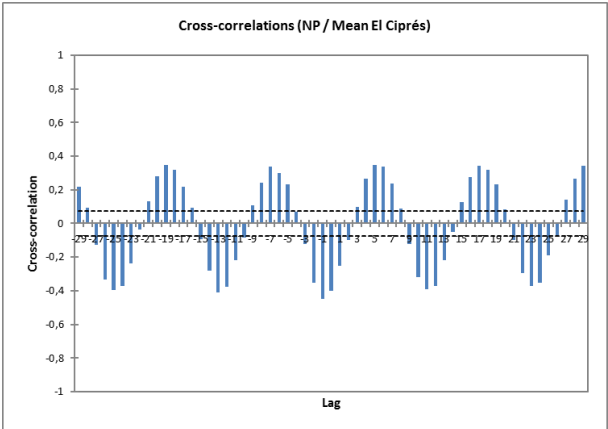


Figure 199 Cross-correlation between the NP index and mean precipitation values at El Ciprés station

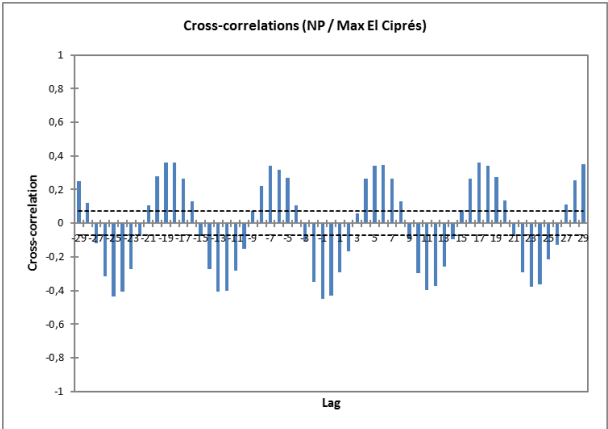


Figure 200 Cross-correlation between the NP index and maximum precipitation values at El Ciprés station

Rainfall Characterization of the Catchment Area of Ensenada, Baja California, México

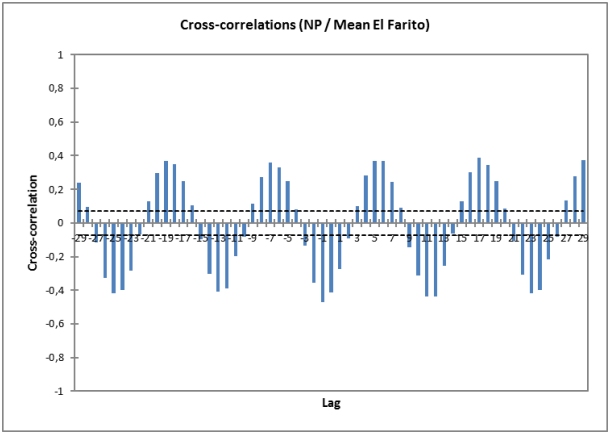


Figure 201 Cross-correlation between the NP index and mean precipitation values at El Farito station

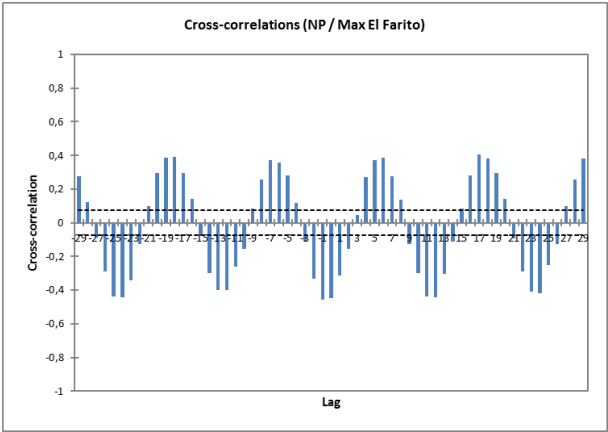


Figure 202 Cross-correlation between the NP index and maximum precipitation values at El Farito station

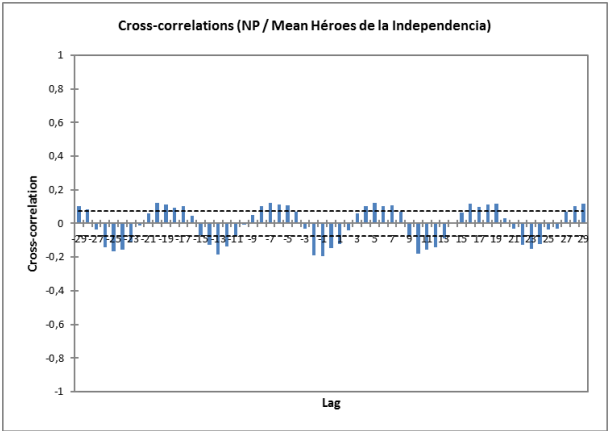


Figure 203 Cross-correlation between the NP index and mean precipitation values at Héroes de la Independencia station

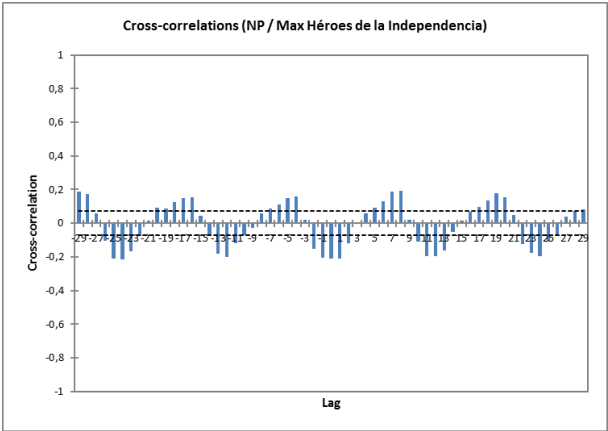


Figure 204 Cross-correlation between the NP index and maximum precipitation values at Héroes de la Independencia station

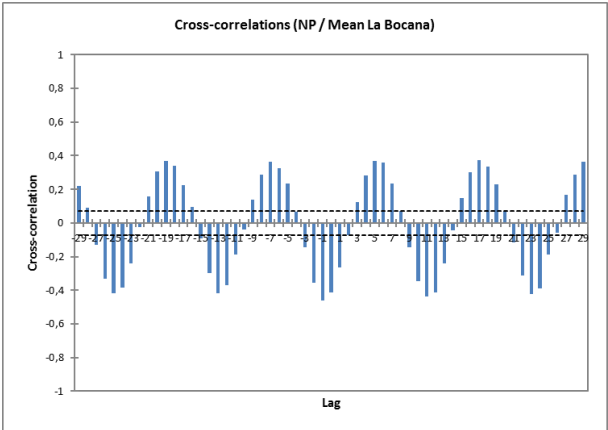


Figure 205 Cross-correlation between the NP index and mean precipitation values at La Bocana station

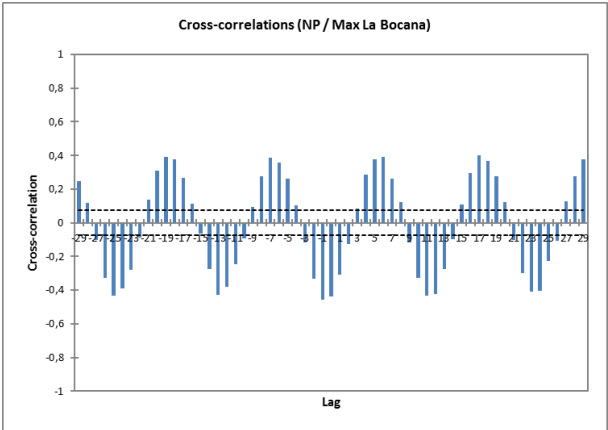


Figure 206 Cross-correlation between the NP index and maximum precipitation values at La Bocana station

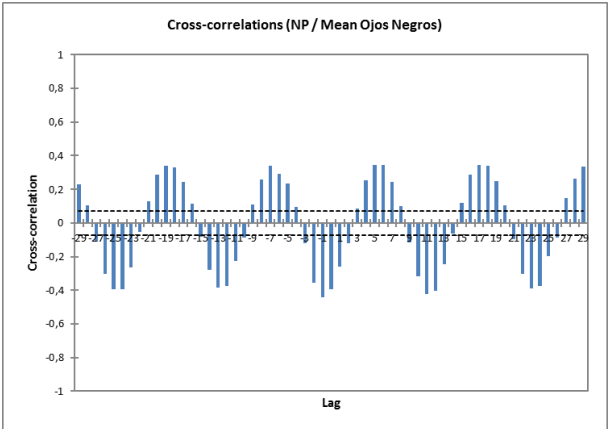


Figure 207 Cross-correlation between the NP index and mean precipitation values at Ojos Negros station

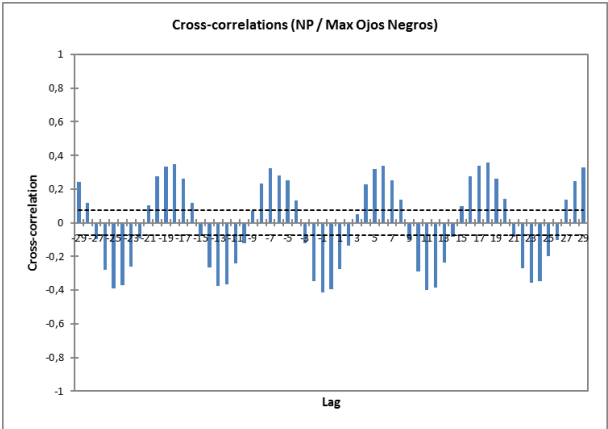


Figure 208 Cross-correlation between the NP index and maximum precipitation values at Ojos Negros station

Rainfall Characterization of the Catchment Area of Ensenada, Baja California, México

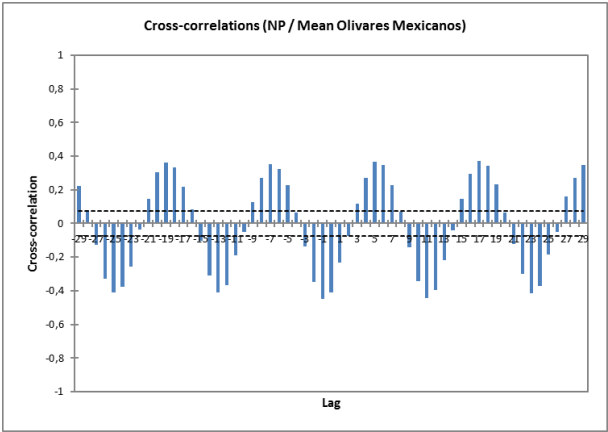


Figure 209 Cross-correlation between the NP index and mean precipitation values at Olivares Mexicanos station

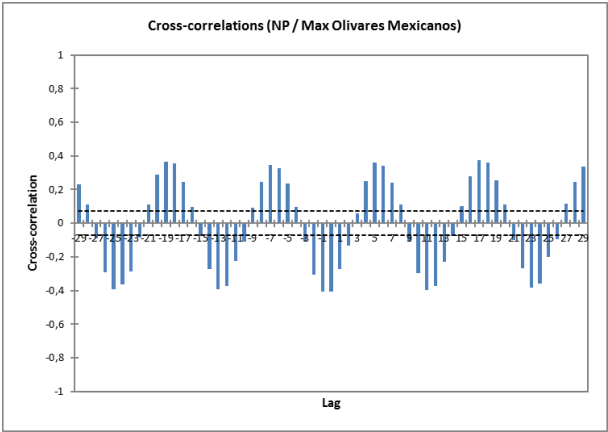


Figure 210 Cross-correlation between the NP index and maximum precipitation values at Olivares Mexicanos station

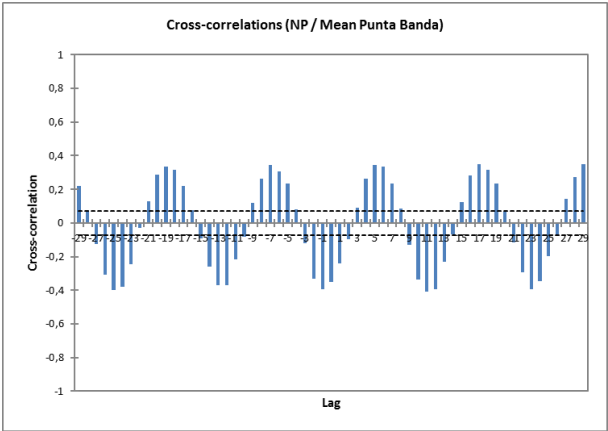


Figure 211 Cross-correlation between the NP index and mean precipitation values at Punta Banda station

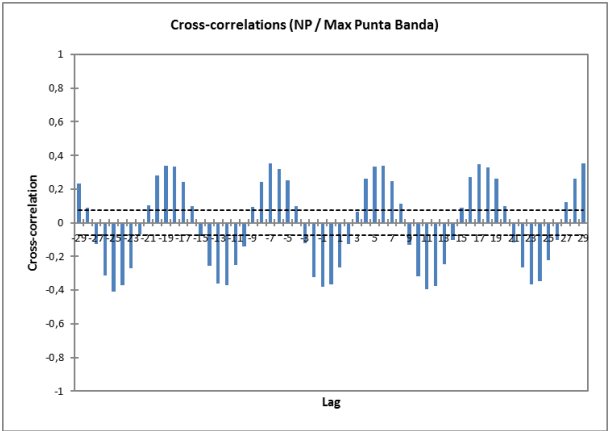


Figure 212 Cross-correlation between the NP index and maximum precipitation values at Punta Bando station

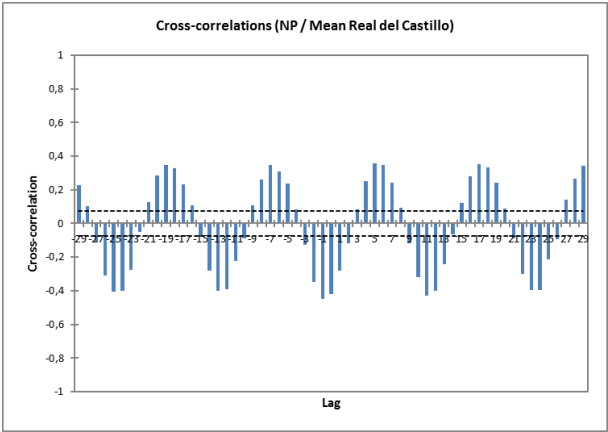


Figure 213 Cross-correlation between the NP index and mean precipitation values at Real del Castillo station

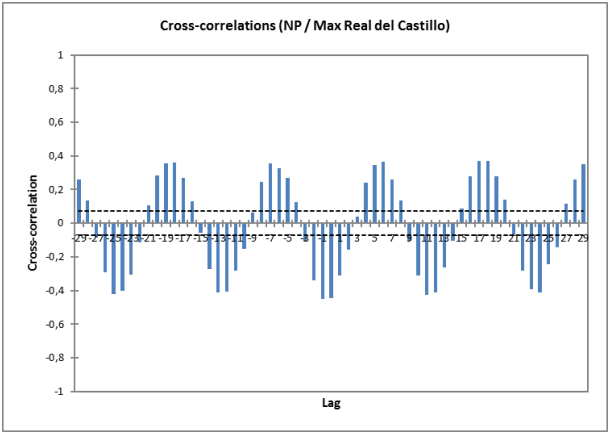


Figure 214 Cross-correlation between the NP index and maximum precipitation values at Real del Castillo station

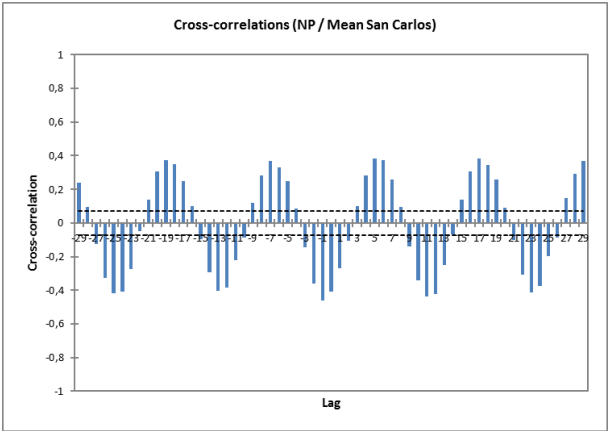


Figure 215 Cross-correlation between the NP index and mean precipitation values at San Carlos station

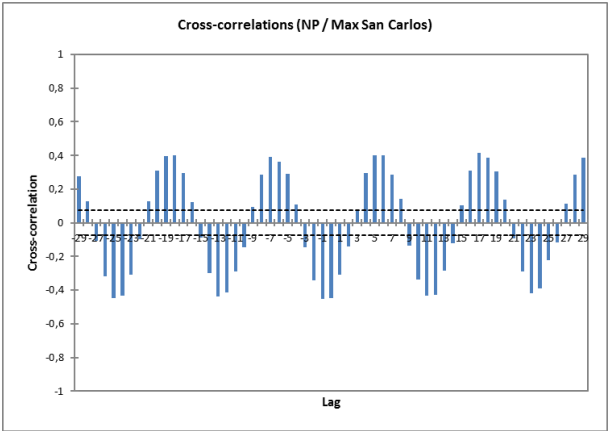


Figure 216 Cross-correlation between the NP index and maximum precipitation values at San Carlos station

Rainfall Characterization of the Catchment Area of Ensenada, Baja California, México

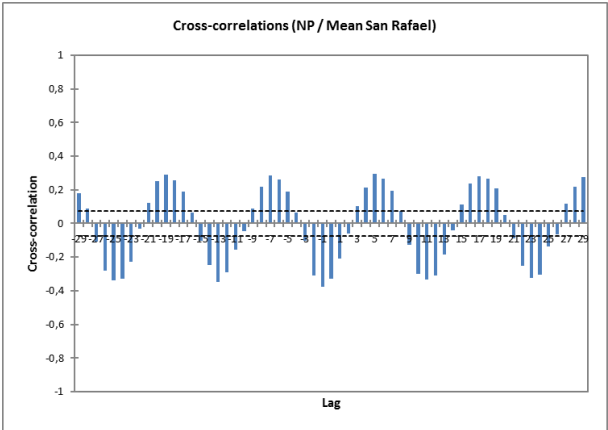


Figure 217 Cross-correlation between the NP index and mean precipitation values at San Rafael station

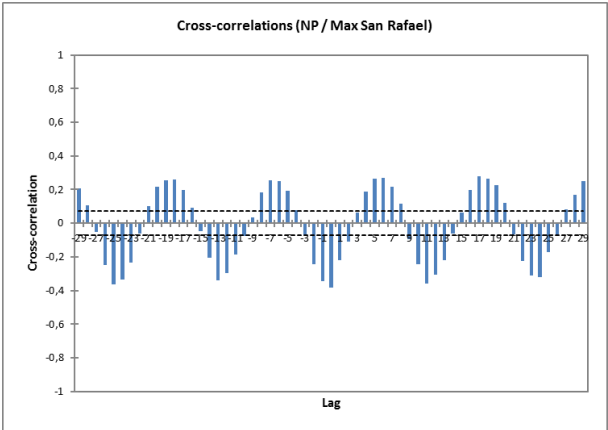


Figure 218 Cross-correlation between the NP index and maximum precipitation values at San Rafael station

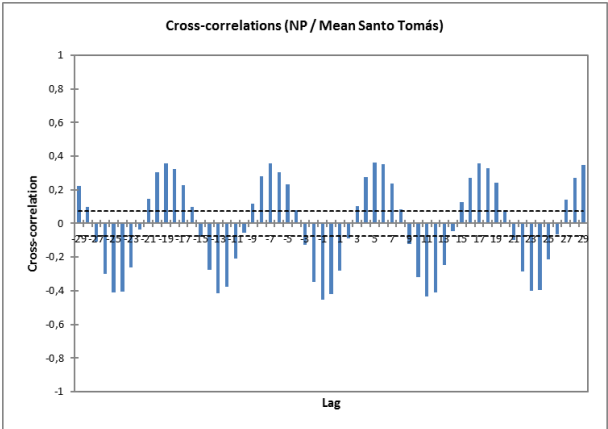


Figure 219 Cross-correlation between the NP index and mean precipitation values at Santo Tomás station

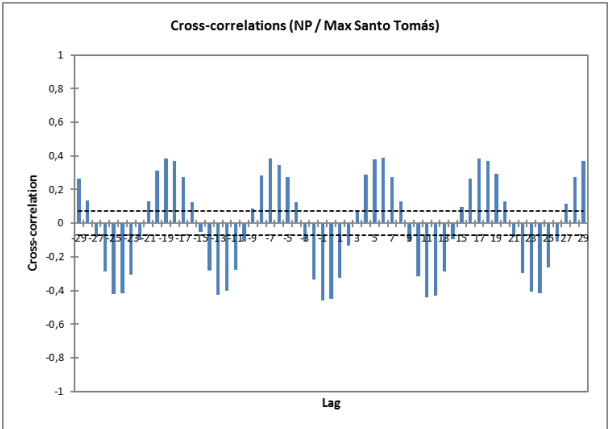


Figure 220 Cross-correlation between the NP index and maximum precipitation values at Santo Tomás station

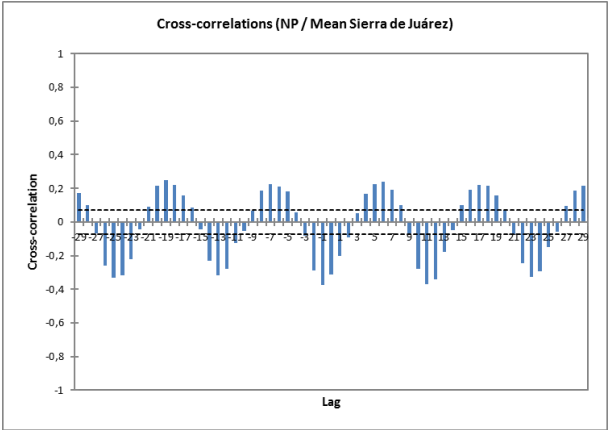


Figure 221 Cross-correlation between the NP index and mean precipitation values at Sierra de Juárez station

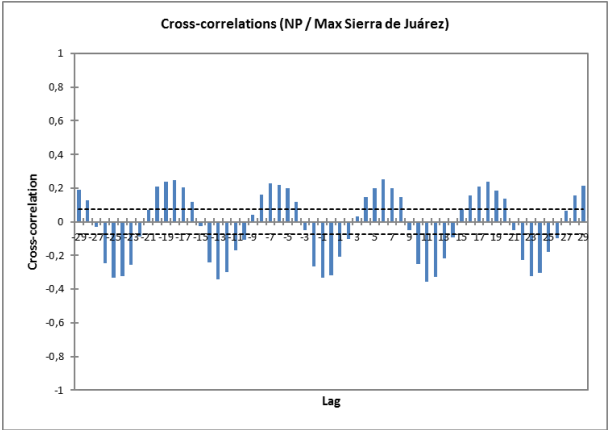


Figure 222 Cross-correlation between the NP index and maximum precipitation values at Sierra de Juárez station

